PB 187 306

RAIL TRANSPORT OF SOLID WASTES

Karl W. Wolf, et al

American Public Works Association
Chicago, Illinois

October 1968

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RAIL TRANSPORT OF SOLID WASTES

a feasibility study

interim report: phase one

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration

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This report is reproduced as received from the grantee. No editorial or other changes have been made, although a title page, foreword, and abstract of the related demonstration grant project have been added as well as a listing of other reports of solid waste demonstration projects.

Since this is an interim report of progress, the conclusions and recommendations presented should be considered as preliminary in nature, pending completion of the project and final evaluation of findings.

PB-187 306

RAIL TRANSPORT OF SOLID WASTES

A Feasibility Study

INTERIM REPORT: PHASE ONE

Prepared by the American Public Works Association
Research Foundation under Grant No. D01-UI-00073.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Bureau of Solid Waste Management
Cincinnati
1969

FOREWORD

An estimated 900 million pounds of solid wastes of all types are produced in the United States every day. What to do with these solid wastes, how to dispose of them without needlessly endangering public health and welfare, and how to recover and reuse valuable materials now "thrown away" are among the most challenging and perplexing of current national problems. Because of lack of suitable planning, interest, and public understanding, these problems have reached such proportions that nationwide attention is demanded and action for the development of adequate solutions must be taken.

Intensified action concerning these problems was made possible by the Solid Waste Disposal Act, Title II of Public Law 89-272, which was signed by the President on October 20, 1965. This legislation directs the Secretary of the Department of Health, Education, and Welfare to initiate, encourage, and support a national program aimed at discovering and evaluating better methods of coping with the solid waste problem.

The Secretary is authorized (1) to conduct and support research on the nature and scope of the problem, on methods of more safely and efficiently collecting and disposing of solid wastes, and on techniques for recovering from solid wastes potentially valuable materials and energy; (2) to provide training and financial and technical assistance to local and State agencies and other organizations in the planning, development, and conduct of solid waste management programs; (3) to encourage and support projects that may demonstrate new and improved methods of solid waste collection, handling, and disposal.

To carry out these responsibilities, the Bureau of Solid Waste Management was established. Among the responsibilities with which the Bureau is charged is that of providing grant support for demonstrations relating to the development and application of new and improved methods of solid waste collection, storage, processing and ultimate disposal; and also for studies and investigations that may lead to a demonstration of improved disposal practices, or may provide solutions for regional or national solid waste disposal problems. Associated with this is the responsibility of collecting and making available by appropriate means the results of, and other information pertaining to, such federally supported demonstrations, studies and investigations.

This interim report (for Phase I of the Rail Haul Demonstration Project) has been reproduced as received from the grantee to disseminate the latest information and findings resulting from the study as quickly as possible. We trust that it will provide those working in the field of solid waste management with information that will be useful in developing approaches to the solutions of solid waste problems.

Review of this report by the Bureau of Solid Waste Management indicated a need for some editing, as well as additional documentation and clarification of certain features of the study, principally the economic justifications presented. The final report for Phase I of the project will be strengthened along such lines.

Additional work is currently underway to complete the project. Future progress reports will also be made available by the Bureau of Solid Waste Management. The final project report will be issued as a Public Health Service publication.

A related report *The Tezuka Refuse Compression System; a preliminary report* will also be published by the Bureau. This was prepared by the APWA Research Foundation in connection with, but not as part of, the Rail Haul Demonstration Project.

--RICHARD D. VAUGHAN, *Director*
Bureau of Solid Waste Management

ABSTRACT OF STUDY AND INVESTIGATION GRANT NO. DO1-UI-00073

TITLE: Investigation of the Potential Benefits of Rail Haul as an Integral Part of Waste Disposal Systems.

GRANTEE: American Public Works Association
1313 East 60th Street
Chicago, Illinois 60637

PROJECT DIRECTOR: Dr. Karl W. Wolf, Research Associate
American Public Works Association Research Foundation
c/o Museum of Science and Industry
Room C-209
57th and South Shore Drive
Chicago, Illinois 60637

PROJECT STARTED: April 1, 1967 PROJECT ENDS: June 30, 1971

[illegible] of the report is

OBJECTIVES: To determine the feasibility of a new method of solid waste disposal by making a comprehensive evaluation of the costs and benefits obtainable for the collection, transportation and disposal of solid wastes from urban areas by the use of rail-haul techniques.

PROCEDURES: The project is being conducted in three phases, each of which is expected to take approximately a year to complete. Phase One is concerned with the identification, development and setting up of the rail haul and related solid waste transport and disposal techniques. Phase Two will deal mainly with implementation of the rail-haul waste disposal concept in cooperation with selected communities. Phase Three will consist of a comprehensive evaluation of the concept and techniques as demonstrated under actual operating conditions during phase two.

The project is being conducted by staff of the American Public Works Association, with contractual professional and consulting services of various types being obtained as needed.

RAIL TRANSPORT OF SOLID WASTES

Interim Report

Prepared by

Karl W. Wolf, Ph.D.
and
Christine H. Sosnovsky, Ph.D.

October, 1968

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*** PREFACE ***

This is an interim report on a research program being conducted by the American Public Works Association and entitled, "An Investigation of the Potential Benefits of Rail Haul as an Integral Part of Waste Disposal Systems." This report covers part of the first phase work of the three-phased demonstration grant--1-D01-UI-00073-01.

The magnitude of interest in this project is a real measure of the critical nature of the problem of solid waste disposal in urban areas. The number of inquiries and requests for progress information on the project has at times inhibited staff efforts to push investigations ahead on an accelerated scale. It became evident that an interim report on some of the results of the work as it has progressed would serve a useful purpose even though only tentative conclusions can be reported in certain key investigative areas.

This $468,000 research project is financed by the Solid Waste Program of the U. S. Department of Health, Education and Welfare, the Penn Central Railroad and many communities such as Marin County, California; the District of Columbia; Chicago and Park Forest, Illinois; the Metropolitan Sanitary District of Greater Chicago, Illinois; Elkhart and Marion County, Indiana; Boston, Massachusetts; Detroit and Grand Rapids, Michigan, the New York Pure Waters Authority, Albany, New York; Hempstead and New York, New York; Akron, Cincinnati, Cleveland, and Columbus, Ohio; Dallas, Texas; Norfolk and Richmond, Virginia; Milwaukee County, Wisconsin; the Municipality of Metropolitan Toronto and the cities of Toronto and Winnipeg, Canada.

This project is an example of the cooperative research undertaken by the APWA Research Foundation for United States and Canadian communities. Through cooperative research, communities pool their resources to solve problems they face in common. This approach enables communities to overcome restrictions of manpower, time and funds and to multiply the value of each research dollar.

It is hoped that the information presented in this interim report will prove to be useful to the many people concerned with solid waste disposal problems. Any comments or suggestions that might be offered to the project staff would be most welcome.

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CHAPTER ONE - INTRODUCTION

This chapter presents the rationale for the existence of the project, states the project objectives, reports on the current status of the research efforts, and describes the nature of the findings included in this interim report.

I. THE RATIONALE FOR THE EXISTENCE OF THE RAIL-HAUL PROJECT

It has been frequently estimated that the nation currently generates 185 to 200 million tons of solid wastes annually. The collection and disposal of these wastes which, by definition, have no economic value, have been estimated to cost $3 billion each year. Thus on a very broad average it costs the nation today 15 to 16 dollars to collect and dispose of one ton of solid wastes. Since the collection is often estimated to account for about two-thirds or three-fourths of the total bill, the disposal expenditures can, in a very broad average, be gauged at $5.00 to $5.35 or $3.75 to $4.00 per ton.

The solid waste disposal problem is especially acute in the densely settled urban areas where most of the nation's socio-economic activities take place. To dimension the generation of solid wastes for these areas, a factor of one ton per capita per year is frequently used. This implies, for example, that in the City of Chicago, containing approximately three million people, about three million tons of solid wastes have to be handled annually. Thus solid waste disposal requirements exhibit all the characteristics commonly found in mass production, mass transportation and mass service.

Furthermore, all currently used disposal methods require at least some land for the ultimate disposition of the wastes or the waste residue. But in the urban areas land is not only in short supply, it is also in strong demand for more attractive or productive uses. In competing for the decreasing amounts of land, solid waste disposal often is left the loser.

As a result more and more wastes need to be shipped out of the immediate areas where they originate. Thus transportation is becoming more and more a requirement in the development of solid waste management systems if the final disposal is to be organized on an "out-of-town" or better still, "regional" or "super-regional" basis. The logic of this situation implies, specifically, that in the overall long distance transport must be evaluated along with volume reduction to an ever increasing degree.

But transportation is not only of importance with respect to the operating radius of a waste disposal system. The basic configurations of a transport network influences significantly the intensity and flexibility with which a given area can be served. Transportation must be viewed also with respect to the spatial distribution of the waste generating areas, the individual governmental jurisdictions and the corresponding waste disposal needs. Transportation, for example, might enable a single disposal site to serve many communities rather than just a few.

Considering now, in combination, the negative economic value of urban solid wastes, the huge quantities involved and the spatial distribution of the waste disposal needs, it becomes obvious that a

> low cost, high tonnage and ubiquitous transportation carrier should be investigated carefully with respect to its use in urban solid waste management systems.

Railroads are a prime example of this type of transportation carrier. They offer many options in terms of both the communities that might be served within a given system and the selection of diverse disposal sites.

II. THE PROJECT OBJECTIVES

To identify the potential benefits of rail haul for waste disposal systems it is necessary to investigate many potential system elements with respect to their value for an acceptable waste rail-haul system. The complexity of this undertaking is reflected in the seven basic objectives of this study. As stated in the project application these objectives require the study team

1. to determine the techno-economic feasibility of using rail-haul equipment and methods currently and potentially available for solid waste operations;
2. to ascertain the advantages and implications of using rail-haul as related to existing local collection practices, equipment, and current disposal techniques;
3. to identify and dimension the transfer operations and facilities needed to move the wastes on, as well as off, the rail carriers;
4. to evaluate the project oriented application potential of established industrial/commercial material handling equipment and processes not presently used in the solid waste field;
5. to arrange for an implementation of the rail-haul concept with one or several selected communities, including multi-community undertakings in metropolitan areas;
6. to measure the practicability, efficiency, economics and safety of the concept, equipment, and techniques; and
7. to detail and define the "by-product" benefits to be derived from the rail-haul concept in terms of new product and process developments, beautification and resource development.

To accomplish these seven basic objectives it is necessary to pursue a large number of corollary subobjectives. According to their orientation these subobjectives may be grouped into highly interrelated substudies concerning:

A. Transfer Stations--how to get the wastes into the system;

B. Rail Transport--how to get the wastes to their final point of disposal;

C. Disposal Operations--how to dispose of the wastes as they are processed through the system, e.g., in large quantities and perhaps in a heretofore not generally used condition;

D. Specific Community Applications--how rail haul would function in an existing community as shown in case studies for a number of communities; and

E. Public Health and Environmental Control--how rail haul implements the applicable requirements progressively throughout its system.

The project is divided into a three-phase effort. The first phase is to produce the following tangible output:

..... a written final report containing a comprehensive simulation study which will outline (a) the cost and performance of a complete waste rail-haul system and (b) a well-documented justification for the selection of a particular system including individual system elements,

..... the setup of one or more demonstration projects in cooperation with selected communities--to test the practicability of various system building block elements, and

..... a tentative writeup of a solid waste rail-haul guide book which will enable public works managers, as well as private enterprise, to evaluate the potential application of the system for their individual situation.

In the overall it must be recognized that the project deals with applied research in terms of a feasibility study and thus is both exploratory and developmental in character. Through this kind of applied research, it will be possible to determine if additional investment is warranted and, if so, in what direction the substantially larger development expenditures for a full-scale solid waste rail-haul system should be spent--in the form of demonstration projects.

III. THE STATUS OF THE SOLID WASTE RAIL-HAUL RESEARCH EFFORTS

The current status of the rail-haul project must be viewed within the context of progress made in the City of Chicago solid waste compression test program. This is the first demonstration project developed by the APWA rail-haul study and is financed by the City of Chicago and the Solid Waste Program of the U. S. Department of Health, Education, and Welfare.

The City of Chicago compression test program, described in detail later in this report, was formulated in November, 1967 and is expected to be operational in November, 1968. It is expected to produce information which will materially enhance the reliability of the findings of the rail-haul project. Involving various waste compositions, pressures up to 6000 psi, and an investigation of many waste compaction variables, the tests are envisioned as requiring about three calendar months for completion. In view of the systemic importance of solid waste compression for solid waste rail haul, it was unavoidable and necessary to restructure all major rail-haul research efforts accordingly.

The APWA rail-haul project and the City of Chicago waste compression test program are highly interdependent. To an unusually high degree the test results will determine the specific form of the key elements of solid waste rail-haul systems. Thus the final report on the first phase of the rail-haul study is expected to be completed approximately three months after the termination of the compression test program.

IV. THE NATURE OF THE FINDINGS PRESENTED IN THIS INTERIM REPORT

It should be stressed that most of the findings reported herein are still tentative. In determining the feasibility and potential benefits of solid waste rail haul it is necessary to balance many system elements simultaneously in terms of both technical performance and economics.

Moreover, the factors determining the feasibility of an acceptable system were found to be unusually interdependent in almost all respects. Thus the very subject matter of this investigation makes it impossible to finalize findings through a succession of neatly confined research phases and to report the results accordingly.

CHAPTER TWO - PRELIMINARY CONCLUSIONS

The conclusions drawn from the information presented in this report suggest that some of the benefits, as indicated in the original project application, appear to be attainable. At present, the benefits potentially achievable through a solid waste rail-haul system, appear to be as follows:

1. A strong possibility of reducing direct waste disposal cost.
   Currently, it is calculated, that solid waste rail haul will cost about \$4.00 to \$4.50 per ton, f.o.b. transfer station, (i.e., not including the cost of local collection). These costs, including investment and operations, break down as follows: transfer station, about \$1.00 to \$1.50 per ton; rail haul, about \$2.00 per ton; and disposal, about \$1.00 per ton.

   In addition, some communities might realize considerable savings in their solid waste collection cost through a strategic location of the transfer stations thus cutting down on local hauling distances and time.

2. A change from inadequate methods of disposal to desirable methods and a reduction of air and water pollution as well as other environmental health hazards.
   Solid waste rail haul does not contribute to air pollution in any significant degree. The extreme flexibility in the location of the disposal site allows a wide choice among sites according to their geological suitability. The cost per ton to provide proper protection against water pollution, when soil conditions require such action, are not expected to be prohibitive because of the size of the disposal operations. Finally the necessary dust, noise and odor controls appear to be achievable conveniently and economically.

3. A better utilization of existing rail installations in urban, as well as, rural areas.
   Solid waste rail haul appears capable of developing a considerable

amount of new business for the nation's railroads. As a matter of fact, solid waste transport might evolve into a proposition ranking it among the largest rail shipment categories. The strong interest of almost all railroads in the hauling of solid wastes is based on their desire for additional revenue without additional investment.

4. A capability for land reclamation and the conversion of worthless mining or other land into an active resource.

   Solid waste rail haul is capable of performing land reclamation without any cost to the respective property owners. In addition, results can be demonstrated fast because of the refuse quantities involved.

5. The establishment of an effective and reliable solid waste disposal system.

   Rail transport of solid wastes appears capable of providing a key link for a relatively complete system of disposal. It tends to require proven system elements and is able to function regardless of the usual changes in weather. Also, it appears to be relatively immune to damages occuring in some parts of the system and will ensure, as a rule, a speedy method of removing solid wastes from high-density urban areas.

6. A potential for widespread application.

   Although the total system configuration and implementation might be quite large, solid waste rail haul appears capable of handling large, as well as small, individual input loads without an undue sacrifice of effectiveness. Most likely, many communities over the entire geographic range of the United States and Canada can participate in the systems that might be developed on a regional, super-regional, state, and/or interstate basis.

7. A high degree of flexibility with respect to the workload.

   Solid waste rail haul can accommodate gradual as well as sudden increases in the total, as well as in the local, workload while requiring only relatively small adaptations in the capacity of the system installation. Conversely, system costs can be cut back drastically if the workload decreases.

8. Attractive implementation opportunities.

Concerning the individual system elements, the experience in other fields of industrial/commercial endeavor indicates that the system

a) is safe to operate,
b) can be implemented rather rapidly, i.e., within twelve months, and
c) offers potential users many options for the organization of the effort.

Thus, it can be stated that the benefits to be derived from a successful completion of this project might go far beyond the waste disposal field. They must be considered within the broad framework of improvements in the total environment and in living conditions.

CHAPTER THREE - BASIC SETTING FOR THE PRESENT SOLID WASTE RAIL-HAUL STUDY

Chapter Three presents the considerations which shaped the basic direction of the rail-haul study. It identifies the major rail-haul/disposal system alternatives, indicates the order of magnitude in the economics of solid waste rail shipments and outlines the decision-making factors in the basic selection of the system to be investigated in this study.

I. BASIC RAIL-HAUL/DISPOSAL SYSTEM ALTERNATIVES

Transport of solid wastes by rail haul can be used as an integral part of several different waste disposal systems. In fact, rail haul can be considered for potential incorporation into all systems in which wastes have to be transported.

Thus, to focus the project properly, it was necessary to identify a variety of alternatives for the overall position of rail haul in waste disposal systems. Based on existing disposal methods, three rail-haul/waste disposal approaches have been considered. The specific configuration of the resulting five major system structures is given on the following page. Local collection is common to each. The remaining elements of the systems include various combinations of transfer stations, rail haul, incineration, sanitary landfilling and composting.

In evaluating the system setups it is important to recognize that each starts where the local collection ends. Furthermore, to be immediately applicable, the rail-haul system will have to be compatible with the collection technologies and practices as they exist now.

MAJOR ALTERNATIVES FOR THE POSITION OF RAIL HAUL AS AN INTEGRAL PART OF WASTE DISPOSAL SYSTEMS

Overall System Number	Position and Number of Major System Building Blocks (a)	(b)	(c)	(d)	(e)
I	Local Collection	Transfer Station	Rail Haul	Sanitary Landfill Disposal	
II	Local Collection	Incineration	Transfer Station	Rail Haul	Sanitary Landfill Disposal
III	Local Collection	Transfer Station	Rail Haul	Incineration	Sanitary Landfill Disposal
IV	Local Collection	Composting	Transfer Station	Rail Haul	Sanitary Landfill Disposal
V	Local Collection	Transfer Station	Rail Haul	Composting	Transport and Sanitary Landfill Disposal*

*Refers to the transport of compost as well as the ultimate disposal of the non-compostible waste items.

The above table of potential major solid waste rail-haul systems shows that rail transport may take place before or after the given waste treatment and/or disposal processes. If technically and economically feasible, large incinerator complexes, for example, could be designed to operate in the countryside where the requirements of environmental control could be met more advantageously. In placing certain waste disposal or treatment processes after the rail-haul link it is recognized that economies of scale, made possible through rail-haul operations, could produce results which smaller operations are unable to achieve.

It should be pointed out, however, that the transportation and disposal operations in particular are not identical for each system. Their specific operating requirements and cost vary and are, of course, interdependent with all the other system building blocks. Incineration, for example, requires the transfer and disposal of both incinerator residues as well as the non-incinerable wastes and composting requires the handling of the non-compostible materials. This analysis tends to show how it is possible for rail haul to be made an integral part of a total solid waste disposal system.

II. THE GENERAL ECONOMICS OF RAIL TRANSPORT OF SOLID WASTES

Rail rates, discussed later in this report, are dependent on specifying each of several dozen variables. Briefly, a rail rate cannot be determined unless one names specifically the origination, the destination, the route or routes traveled, the type and size of cars used, the volume transported, the schedule frequency, and the type of service required. Nevertheless, it is considered desirable to serve the purpose of this interim report by generalizing on rates in a very broad way in order to indicate the order of magnitude of rail shipment cost.

There is a substantial cost difference between small and large volume shipments. If either incineration or composting are to be considered an exclusive waste disposal system, the amount of residue or process wastes left for shipment from these processes alone may not be large. The order of magnitude in the economics of small volume shipments is as follows:

AVERAGE ECONOMIC BENCHMARKS
in Dollars Per Ton
FOR THE SMALL VOLUME SHIPMENT OF
SOLID WASTE BY RAIL CARS ATTACHED TO REGULAR TRAINS*

Net Load Capacity per Car (tons)	Shipping Distance (miles)		
	50	100	150
50	$5.05	$5.65	$6.30
70	3.70	4.10	4.65
80	3.25	3.75	4.15
100	2.65	3.00	3.45

Source: Communication from the Penn Central Railroad, 1968
* These rates are based on full carloads, and railroad owned cars.

The preceding figures portray the magnitude of some of the tradeoffs that are available in small volume shipments. It should be stressed that these data represent broad averages and that the cost for a particular situation may show considerable variation. Nevertheless, these figures are of value in guiding the basic direction of research efforts, since the feasibility and evaluation of an initial solid waste rail-haul system cannot be based upon the individual conditions of a single local situation.

Thus, the preceding figures may be used to gauge the impact of rail haul on existing waste disposal processes as outlined in the solid waste rail-haul basic system alternatives II and IV. If a 1000 ton per 24-hour day incinerator generates, for example, 200 tons of residue per day, the rail haul itself would add $530 to the residue disposal cost if the residue were shipped 50 miles in 100 ton cars. The cost roughly would increase to $1,010 if the same amount were shipped in 50 ton cars.

The economics of rail transport change considerably if large volumes of wastes need to be transported. These economics can be exemplified by unit train or rent-a-train operations. Unit train rates, for example, currently concentrate in the range of $1.50 to $2.00 per ton of material shipped and quotes of three to seven mills per ton per mile are not uncommon.

The shipment of large volumes in solid waste rail haul affords considerable flexibility in developing the feasibility of a given system. It applies to the basic system alternatives I, III and V since the materials may be disposed of and/or salvaged by various methods, including incineration and/or composting, at the end of the haul.

III. THE SELECTION OF THE BASIC SOLID WASTE RAIL-HAUL SYSTEM TO BE INVESTIGATED FURTHER IN THE PRESENT STUDY

The selection of the basic solid waste rail-haul system to be studied in this project results from a combination analysis of the existing waste disposal methods and rail-haul parameters.

In evaluating the applicability of the existing waste disposal methods for solid waste rail haul it must be recognized that both incineration and composting represent only partial disposal methods. A well designed sanitary landfill in contrast is capable of accommodating almost all kinds of solid waste materials.

Furthermore, the cost for just the incineration and composting processes appear to be relatively high already. The cost of incineration per ton of combustible wastes is estimated to range from about $5.00 to $7.00 for new installations using the most up-to-date technologies. Any pretreatment of wastes such as the shredding of oversized materials would increase the costs even more. These costs would be part of the incineration/waste rail-haul system in addition to the other unavoidable rail and disposal costs incurred.

The cost of composting, on the other hand, is estimated roughly to be in the same range as the incineration cost. The key disadvantage of composting in the United States is, however, the lack of markets for the end product.

In contrast, the average cost of sanitary landfilling is reported to range from $0.50 to $2.00 per ton. Thus, in terms of the process cost of existing methods, it can be concluded that a combination of rail haul and sanitary landfill offers the best promise for the development of an economical solid waste rail-haul approach.

In the light of the foregoing arguments it was concluded that the basic solid waste rail-haul system for this study should not be one in which either incineration or composting are indispensible building blocks. Thus the basic system alternative I, transfer station/rail haul/sanitary landfill was selected for further exploration, development and evaluation.

This conclusion is supported by the fact that large volume rail shipments promise substantial transport economics. In addition, this conclusion allows for enough system development flexibility to consider the impact of both incineration and composting on solid waste rail haul.

Finally, this conclusion also sets initially the competitive framework within which the feasibility of solid waste rail haul must be determined. To be competitive solid waste rail haul must at least meet the cost currently incurred in local incineration and/or composting. In terms of system development, it should cost less than the existing and/or available incineration and composting methods in order (a) to anticipate near future innovations and improvements in these fields and (b) to provide maximum benefits to the public agencies involved at both ends of the line and to the citizens they represent.

CHAPTER FOUR - THE METHODOLOGY FOR THIS STUDY

Chapter Four describes the general character of the present solid waste rail-haul study and discusses the position and relevance of major study problem areas with respect to the total system.

I. THE GENERAL CHARACTER OF THE PRESENT SOLID WASTE RAIL-HAUL STUDY

The general character of the present solid waste rail-haul study exhibits three distinctive traits. It identifies the project (1) as a feasibility study which (2) deals with a complex subject and (3) is aimed by necessity at a detailed conceptualization of a suitable solid waste rail-haul system.

1. The Nature of the Study: A Thorough Feasibility Analysis

To identify and, as far as possible, dimension the potential benefits of a heretofore nonexistent solid waste rail-haul system, it is necessary that any initial research take the form of a feasibility study. Feasibility denotes the capability of being used, carried out or dealt with successfully. To ascertain feasibility both exploratory and developmental research activities are needed.

Feasibility, for this study, concerns both the technical and economical feasibility of solid waste rail haul. If the system cost were of no consideration at all, it might be stated categorically that solid waste rail haul is technically feasible and can be executed under conditions of virtually perfect environmental control. Wastes, for example, could be packaged, colored, baled, perfumed, sterilized and shipped in highly specialized cars. Furthermore, a solid waste rail-haul system could serve every community if only technical problems had to be solved and the economics were of absolutely no concern.

The requirement of economic feasibility, however, introduces considerable system development constraints. It compounds the difficulty of finding solutions to apparently strictly technical problems. Within the constraints of economics it is no longer possible to accept just any technical solution regardless of how advanced or elegant or attractive it may be.

The requirements of economic feasibility, of course, are of paramount importance for system development aspects where technical problems primarily do not occur. These aspects concern, for example, the organization of the system setup, the selection of certain types of equipment, the location and layout of transfer stations or disposal sites, the route selection, the organization of operations, and the rate-volume shipment relationships.

Since this study addresses itself to the real life feasibility and applicability of solid waste rail haul, it appears necessary to emphasize economic cost/performance parameters in decisions on all major system development alternatives. This emphasis, however, must be placed within a concept of total community benefits designed not only to enhance public acceptance but to create positive support for the project as well.

Finally, in developing the feasibility of a workable solid waste rail-haul system, the project of necessity gets deeply into problems of applied pricing and the corresponding pricing strategies. This occurs not only on all levels of the system itself, but also in areas concerning competitive modes of disposal. An uncritical acceptance of technical or economic claims thus might not only misguide but perhaps even discourage promising development efforts. Within the context of this study any uncritical acceptance of claims might also make the

Federal Solid Wastes Program and the American Public Works Association a party to undesirable pricing, and thus undesirable disposal method development patterns.

2. The Subject: Interdependence of Many Complex Variables

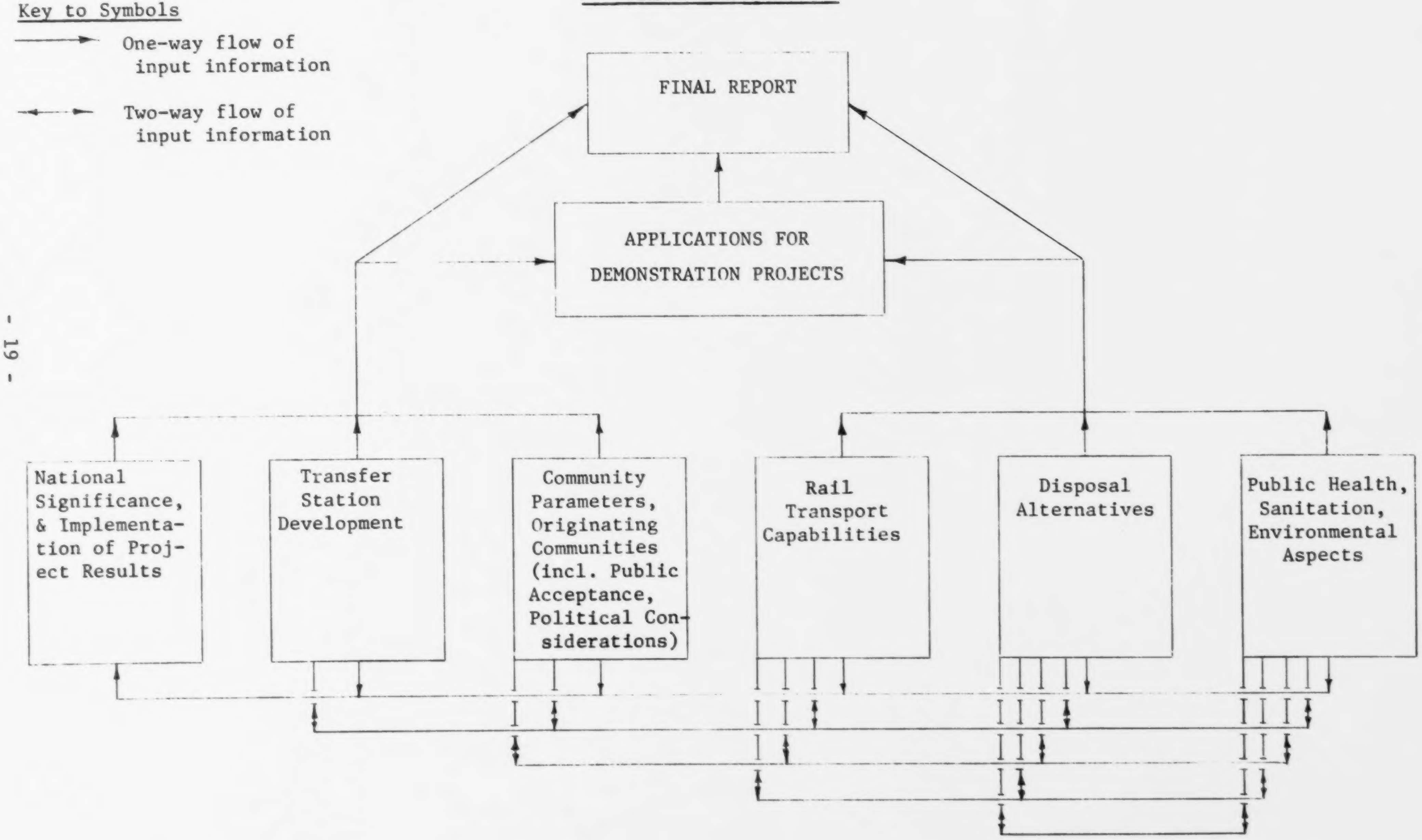
As shown in Exhibit I on the following page, the project concerns the feasibility of a system in which the major building blocks and subsequently their individual elements are closely integrated, interrelated and interdependent. The transfer station development, for example, influences the rail transport capabilities which, in turn, influence the selection of the communities that might be served and the operations at the disposal site. The community parameters, on the other hand, provide inputs for the transfer station development, the selection of rail-haul capabilities and the disposal requirements.

Consequently, the establishment of a suitable solid waste rail-haul system with many independent as well as dependent variables necessitates that individual system elements be developed on a broad front. The production of the various system inputs must be closely synchronized. The inputs have to be unfolded simultaneously in order to balance the total approach judiciously. This requires that many potential study items be given at least some attention at first, with the particular emphasis changing as the total project evolves.

As a consequence, the project requires a substantial information retrieval effort to explore the broad fields of public works and industrial technologies with respect to their usefulness in a potential solid waste rail-haul system. But, as indicated above, the project does not stop there since mere exploration only ascertains facts as they exist now. To establish suitable

EXHIBIT I
APWA SOLID WASTE RAIL-HAUL PROJECT

THE INTERDEPENDENCE OF MAJOR ELEMENTS


Key to Symbols
One-way flow of input information
Two-way flow of input information
FINAL REPORT
APPLICATIONS FOR DEMONSTRATION PROJECTS
National Significance, & Implementation of Project Results
Transfer Station Development
Community Parameters, Originating Communities (incl. Public Acceptance, Political Considerations)
Rail Transport Capabilities
Disposal Alternatives
Public Health, Sanitation, Environmental Aspects

interdependence relationships it is often necessary to transfer and, in this process, transform both technologies and knowledge for solid waste rail-haul applications.

3. A Detailed Conceptualization of a Solid Waste Rail-Haul System

The development and establishment of a suitable solid waste rail-haul system involves, like the development of all technologies, an evolutionary process. In identifying and dimensioning both problem areas and potential solutions, as far as possible, this project positions itself at the very beginning of the evolution.

Correspondingly, this study is not designed to develop, within the context of a narrow and well defined project scope, specific new techniques which require significant efforts in fundamental or applied research. Also, this study has not been conceived to engage in actual product or process development work as defined by the National Science Foundation, i.e., the establishment and operation of actual pilot undertakings. Rather, this study is to lead into such undertakings as exemplified by the City of Chicago refuse compression test program.

II. THE SYSTEMIC POSITION AND RELEVANCE OF MAJOR STUDY PROBLEM AREAS

The systemic position of major study problem areas describes the study elements shown in Exhibit I in terms of some specific problems to be analyzed and/or solved. However, it must be stressed that the solution of each individual problem can only be accomplished by a process of progressive approximation due to the manifold problem interdependence.

The systemic position and relevance of the major study problem areas becomes apparent by grouping as is shown in Exhibit II.

EXHIBIT II

APWA SOLID WASTE RAIL-HAUL PROJECT

THE SYSTEMIC POSITION OF MAJOR STUDY PROBLEM AREAS

	Major Problem Area	Correlated Substudy Efforts*
I.	Criteria for Evaluating Rail-Haul of Solid Wastes	None
II.	The Composition and Volumes of Solid Wastes for Rail-Haul Systems	1. Detailed identification of chemical constituents and properties. 2. Evaluation of the potential impact and significance of salvage operations for solid-waste-rail-haul.
III.	The Transfer of Solid Wastes into the Rail-Haul System a) unprocessed solid wastes b) processed solid wastes ba) chemical processing bb) mechanical processing bba) size reduction bbb) compaction c) material handling requirements d) transfer station layout	1. The feasibility and value of chemical processing for the shipment of solid wastes by rail. 2. The feasibility and value of size reduction (shredding) for the shipment of solid wastes by rail. 3. Exploratory spot testing of processing solid wastes by compaction.
IV.	Public Health and Environmental Control Factors in Solid-Waste-Rail-Haul a) pathogens b) chemical pollution c) nuisance effects d) vector control (insects & rodents) e) aesthetics f) safety	Identification of basic solid waste public health, nuisance and other environmental impact factors.
V.	Rail Transport Capabilities a) rail car selection b) train configuration c) network analysis d) rail rates and costs	The comparative economics of non-rail modes of transport for the long distance haul of solid wastes.
VI.	Sanitary Landfill Disposal in Conjunction with the Rail-Haul of Solid Wastes a) the scale-up of operations in normal landfill methods b) the disposal implications of processed wastes c) disposal in active strip mines	Evaluation of alternatives for integrating strip mine operations with solid waste disposal.
VII.	The Organizational, Financial and Legal Implementation of Transporting Solid Wastes by Rail a) the role of state governments b) typology of communities for solid-waste-rail-haul c) implications of service life on contractual arrangements d) development of solid waste disposal as a positive community resource	Solid-waste-rail-haul studies for selected communities.

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* These substudy efforts are being undertaken in order (a) to establish the necessary input information not suitably available or (b) to provide the needed perspective with regard to the main study results.

Seven groups are identified and some selected arguments are given in the following discussion. In evaluating the scope and depth of the respective project efforts it must be remembered that due to a lack of solid waste research in the past, the varied information as needed is not readily available. Thus, to enhance the dependability of both findings and recommendations, it was necessary to devote considerable efforts to subjects which, at a superficial glance, might not appear directly related to the mere transport of solid wastes by a rail car.

1. Criteria for Evaluating Rail Haul of Solid Wastes

Criteria or yardsticks are of key importance for a feasibility study aimed at the development and evaluation of a system in which cost/performance relationships are decisive. By establishing the characteristics of an ideal system, the criteria provide guidance for the identification and dimensioning of problem areas, the allocation of efforts, and the evaluation of given or potential trade-off alternatives.

The solid waste rail-haul criteria are being developed through an analysis of waste disposal needs as well as the existing disposal operations and their ramifications.

2. The Composition and Volumes of Solid Wastes for Rail-Haul Systems

To investigate the feasibility of solid waste rail haul in a logical way it is necessary first to identify the composition and volumes of the solid wastes that might go into a system.

All types of solid wastes are being considered including residential, municipal, commercial, industrial and demolition wastes. The project deals with this problem in its entirety and on a broad front. The data are being developed through research based on published information as well as the community workshop which is conducted for communities participating in the project.

The composition, characteristics and volumes of the solid wastes are of importance with respect to

a) the type and degree, if any, of processing required in order to make the materials acceptable for solid waste rail haul, and

b) the specific system configuration, e.g., regular or dedicated train service, perhaps dual landfill operations to accommodate processible and unprocessible wastes, and of course, the operational implementation of public health and environmental control requirements.

However, the composition and volume of solid wastes might change substantially, if large scale solid waste salvage methods should be successfully developed. If, for example, a substantial amount of the paper or metals could be salvaged, the solid waste processing requirements as well as the demands on the system would change drastically.

Due to the significance of salvaging for solid waste rail haul it was necessary to devote considerable attention to this problem for the reasons:

a) there is great emphasis on converting solid waste back into a positive national resource as soon as possible, and

b) solid waste rail haul appears to require a relatively long system service period due to the investments involved.

Finally, the interdependence of waste composition and volume with other study problem areas is highlighted by the possibility that some types of wastes might not be acceptable in an initial solid waste rail-haul system. The composition and volume benchmark data thus will provide the needed yardsticks for dimensioning both the initial feasibility of the concept as well as the value and direction of further development efforts.

3. The Transfer of Solid Waste into the Rail-Haul System

The transfer of the wastes from the delivery vehicle into the rail-haul system represents the first major system building block. The transfer may be executed in several, sometimes mutually exclusive ways. Distinguishing mainly between the material processing methods and the corresponding material handling, the transfer approaches may be outlined as follows:

a) transfer of unprocessed solid waste, i.e., as delivered, and
b) transfer of processed waste materials which have been subjected to
    ba) chemical processing methods or
    bb) mechanical processing including
        bba) size reduction (shredding) and/or
        bbb) compaction, and
c) various combinations of the above approaches.

Project efforts are underway to identify, as far as possible, the specific feasibility and value of these major transfer approaches for solid waste rail haul. With respect to the transfer/processing approach, it should be highlighted that in this way, rail haul may develop into an almost completely new system on its own. The material processing analyses are necessary to determine the feasibility of achieving maximum payloads per car and consequently a reduction of the transportation costs, and/or other benefits.

Concerning the processing of solid wastes, it appears that the mechanical processing methods offer the most immediate promise. It was felt necessary to investigate, specifically, the application potential of size reduction in some detail since this process appears to provide a major development alternative.

Research on the compaction of solid wastes will be conducted within the framework of the City of Chicago refuse compression test program. This program deals with low, medium and high pressure applications. The desirability of a systematic solid waste compression test program was established by exploratory compaction spot testing performed within the context of the rail-haul project.

The interdependence of the transfer station developments with the other system elements is obvious. Chemical processing, i.e., in particular material dissolution, might require tank cars for the transport. Size reduction and a nonprocessing of the wastes necessitate disposal operations different from those advantageous for highly compacted material. The composition, volume, transport and disposal alternatives determine, in turn, how far to go with what processing methods.

It is obvious that the transfer station development for solid waste rail haul represents a complex problem with many alternatives and interdependent variables. The scope of the study approach in this area is indicated in Exhibit III on the following page. In reading the Exhibit it should be recognized, of course, that all the items listed do not receive an equal amount of staff attention.

EXHIBIT III
APWA SOLID WASTE RAIL-HAUL PROJECT
PAGE 1

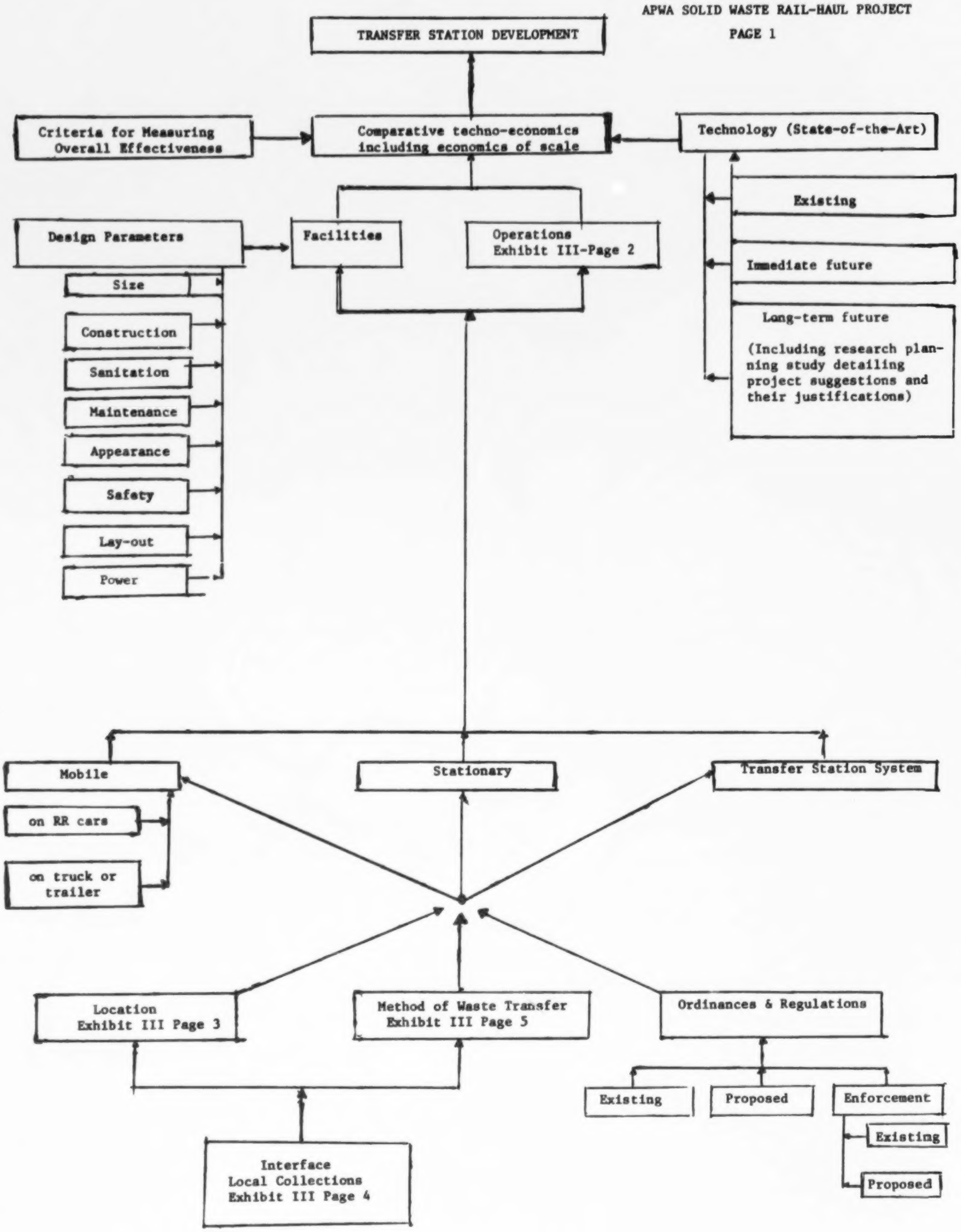

TRANSFER STATION DEVELOPMENT
Criteria for Measuring Overall Effectiveness
Comparative techno-economics including economics of scale
Technology (State-of-the-Art)
Existing
Immediate future
Long-term future
(Including research planning study detailing project suggestions and their justifications)
Design Parameters
Size
Construction
Sanitation
Maintenance
Appearance
Safety
Lay-out
Power
Facilities
Operations Exhibit III-Page 2
Mobile
on RR cars
on truck or trailer
Stationary
Transfer Station System
Location Exhibit III Page 3
Method of Waste Transfer Exhibit III Page 5
Ordinances & Regulations
Existing
Proposed
Enforcement
Existing
Proposed
Interface Local Collections Exhibit III Page 4

EXHIBIT III

APWA SOLID WASTE
RAIL-HAUL PROJECT

Page 2

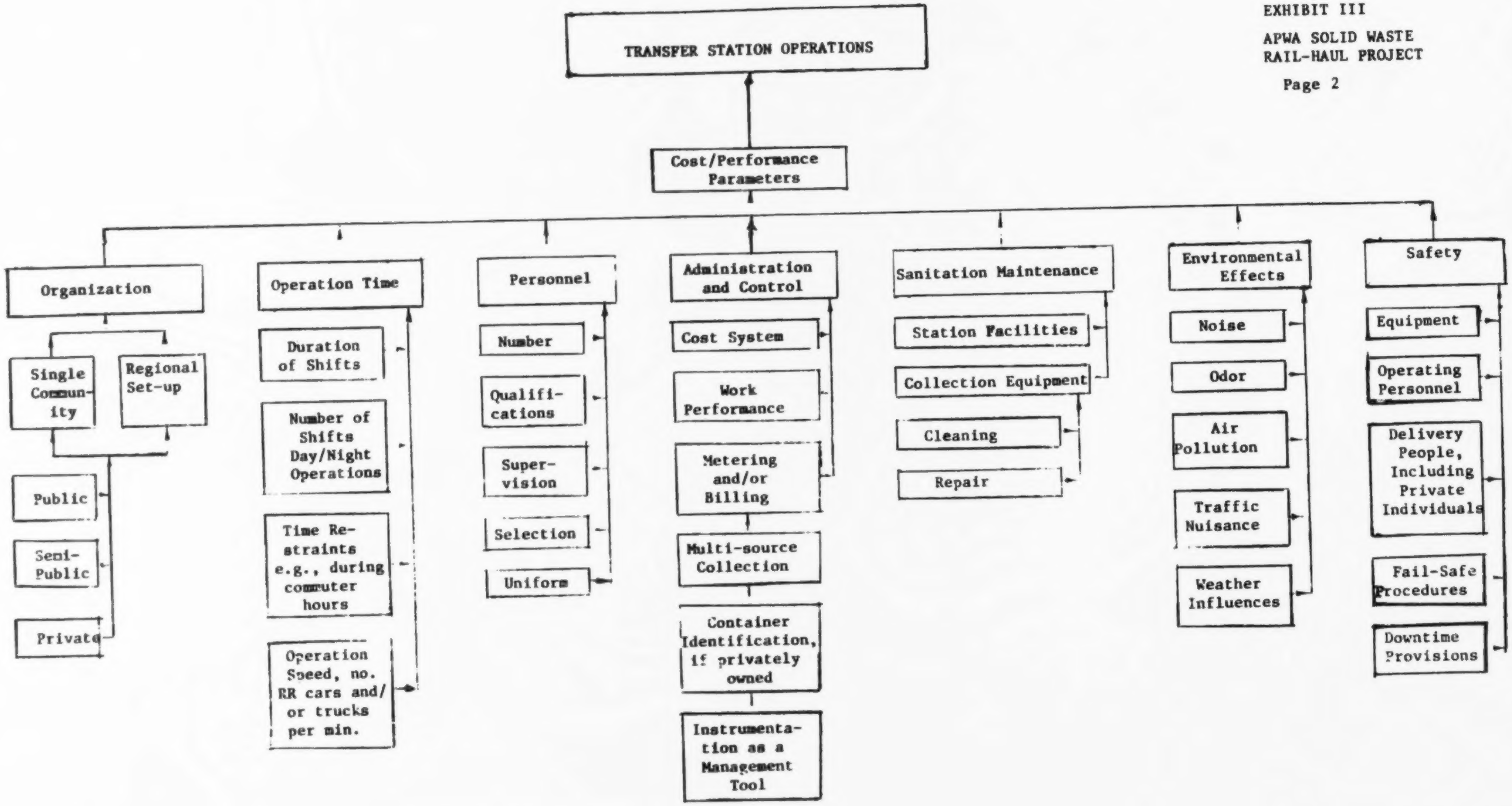

TRANSFER STATION OPERATIONS
Cost/Performance Parameters
Organization
Single Commun-ity
Regional Set-up
Public
Semi-Public
Private
Operation Time
Duration of Shifts
Number of Shifts Day/Night Operations
Time Re-straints e.g., during commuter hours
Operation Speed, no. RR cars and/or trucks per min.
Personnel
Number
Qualifi-cations
Super-vision
Selection
Uniform
Administration and Control
Cost System
Work Performance
Metering and/or Billing
Multi-source Collection
Container Identification, if privately owned
Instrumenta-tion as a Management Tool
Sanitation Maintenance
Station Facilities
Collection Equipment
Cleaning
Repair
Environmental Effects
Noise
Odor
Air Pollution
Traffic Nuisance
Weather Influences
Safety
Equipment
Operating Personnel
Delivery People, Including Private Individuals
Fail-Safe Procedures
Downtime Provisions

EXHIBIT III

APWA SOLID WASTE
RAIL-HAUL PROJECT

Page 3

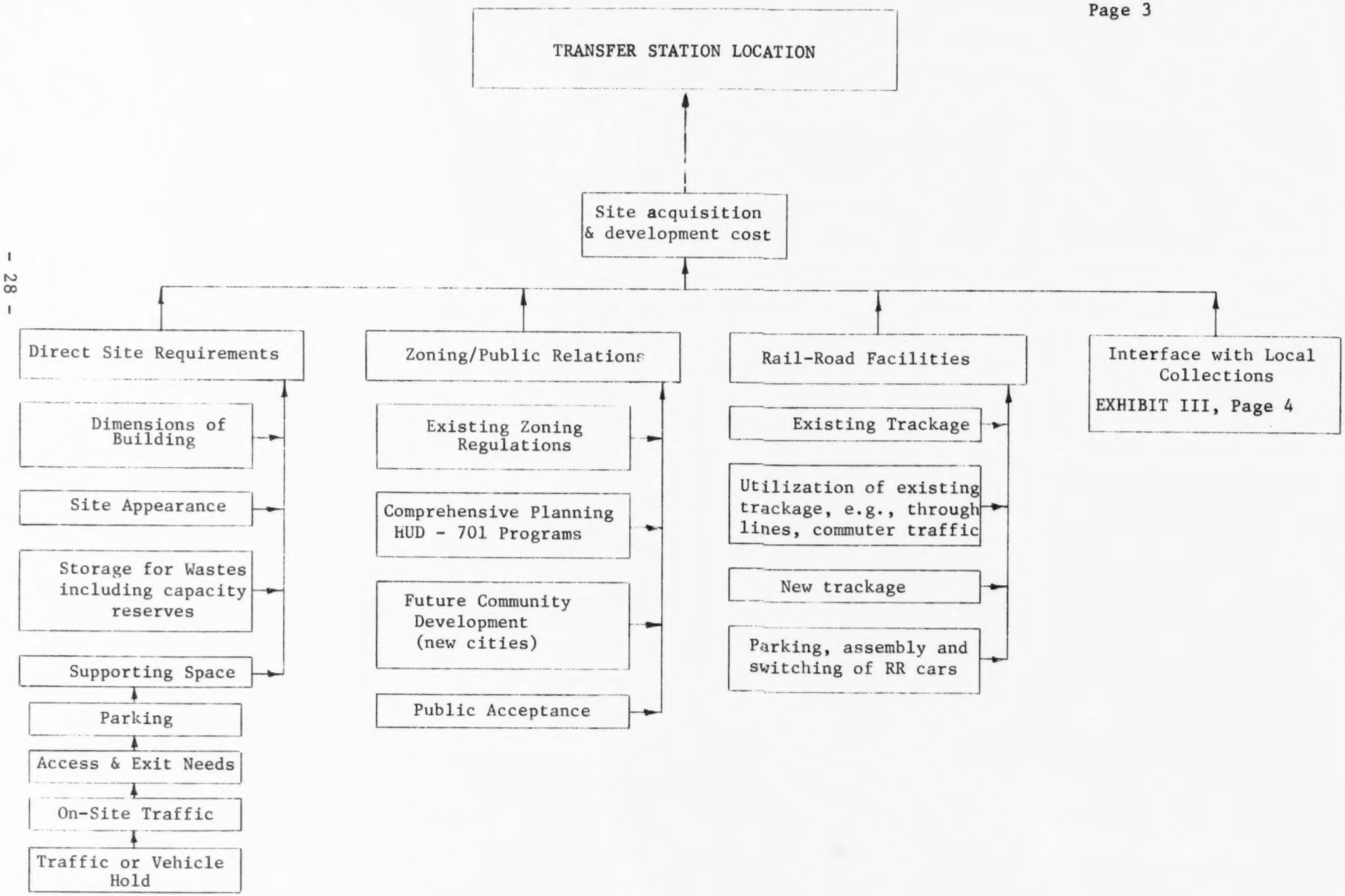

TRANSFER STATION LOCATION
Site acquisition & development cost
Direct Site Requirements
Dimensions of Building
Site Appearance
Storage for Wastes including capacity reserves
Supporting Space
Parking
Access & Exit Needs
On-Site Traffic
Traffic or Vehicle Hold
Zoning/Public Relations
Existing Zoning Regulations
Comprehensive Planning HUD - 701 Programs
Future Community Development (new cities)
Public Acceptance
Rail-Road Facilities
Existing Trackage
Utilization of existing trackage, e.g., through lines, commuter traffic
New trackage
Parking, assembly and switching of RR cars
Interface with Local Collections
EXHIBIT III, Page 4

EXHIBIT III

APWA SOLID WASTE
RAIL-HAUL PROJECT
Page 4

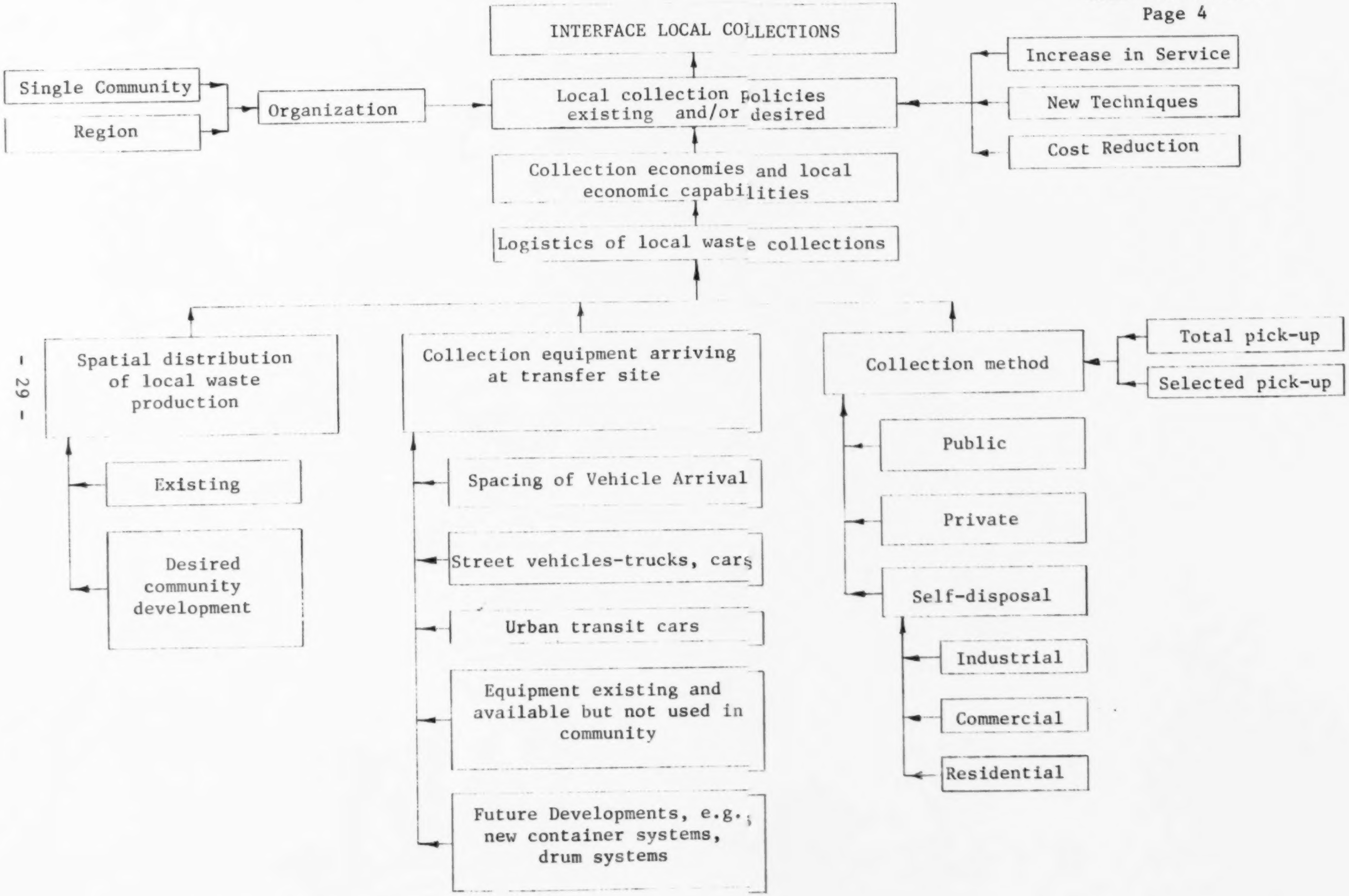
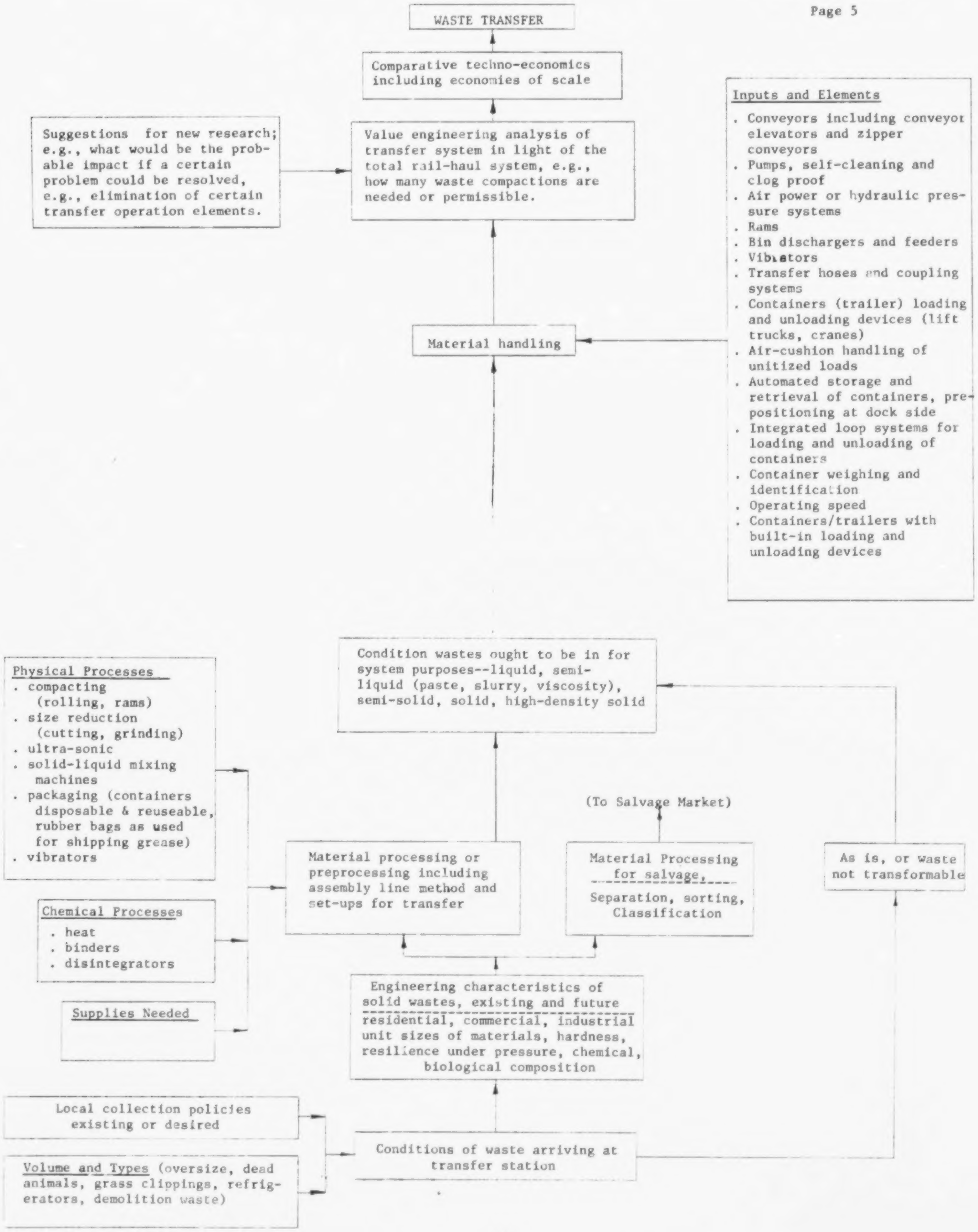

INTERFACE LOCAL COLLECTIONS
Single Community
Region
Organization
Local collection policies existing and/or desired
Increase in Service
New Techniques
Cost Reduction
Collection economies and local economic capabilities
Logistics of local waste collections
Spatial distribution of local waste production
Existing
Desired community development
Collection equipment arriving at transfer site
Spacing of Vehicle Arrival
Street vehicles-trucks, cars
Urban transit cars
Equipment existing and available but not used in community
Future Developments, e.g., new container systems, drum systems
Collection method
Total pick-up
Selected pick-up
Public
Private
Self-disposal
Industrial
Commercial
Residential

EXHIBIT III

APWA SOLID WASTE
RAIL-HAUL PROJECT

Page 5


WASTE TRANSFER
Comparative techno-economics including economies of scale
Suggestions for new research; e.g., what would be the probable impact if a certain problem could be resolved, e.g., elimination of certain transfer operation elements.
Value engineering analysis of transfer system in light of the total rail-haul system, e.g., how many waste compactions are needed or permissible.
Inputs and Elements
. Conveyors including conveyor elevators and zipper conveyors
. Pumps, self-cleaning and clog proof
. Air power or hydraulic pressure systems
. Rams
. Bin dischargers and feeders
. Vibrators
. Transfer hoses and coupling systems
. Containers (trailer) loading and unloading devices (lift trucks, cranes)
. Air-cushion handling of unitized loads
. Automated storage and retrieval of containers, prepositioning at dock side
. Integrated loop systems for loading and unloading of containers
. Container weighing and identification
. Operating speed
. Containers/trailers with built-in loading and unloading devices
Material handling
Condition wastes ought to be in for system purposes--liquid, semi-liquid (paste, slurry, viscosity), semi-solid, solid, high-density solid
Physical Processes
. compacting (rolling, rams)
. size reduction (cutting, grinding)
. ultra-sonic
. solid-liquid mixing machines
. packaging (containers disposable & reuseable, rubber bags as used for shipping grease)
. vibrators
(To Salvage Market)
Material processing or preprocessing including assembly line method and set-ups for transfer
Material Processing for salvage,
Separation, sorting, Classification
As is, or waste not transformable
Chemical Processes
. heat
. binders
. disintegrators
Supplies Needed
Engineering characteristics of solid wastes, existing and future
residential, commercial, industrial unit sizes of materials, hardness, resilience under pressure, chemical, biological composition
Local collection policies existing or desired
Volume and Types (oversize, dead animals, grass clippings, refrigerators, demolition waste)
Conditions of waste arriving at transfer station

4. Public Health and Environmental Control Factors in Solid Waste Rail Haul

The public health and environmental control aspects of solid waste rail haul are strongly influenced by the composition and volumes of the materials that go into the system and by any processing that might be applied. Public health and environmental control considerations, in turn, influence on their own the selection and combination of specific material processing approaches.

The study efforts with respect to this problem group deal with pathogens, chemical pollution, nuisance effects, vector control, aesthetics, and safety. Public health and environmental control problems arise, of course, in all building blocks of a solid waste rail-haul system.

It should be emphasised that these problems will receive specific attention in the City of Chicago refuse compression test program since the processing of wastes might provide systemwide environmental control benefits. In this respect, the trade-offs between processing cost and the provisions required in other parts of the system might be quite significant.

5. Rail Transport Capabilities

The alternatives of shaping or structuring rail haul for integration in solid waste disposal systems are numerous. they relate, of course, to all major project efforts. In addition to the transfer station and the disposal, the rail haul constitutes the third major building block for determining the feasibility of a solid waste rail-haul system.

The rail-haul investigation concerns itself with

a) the rail car selection and/or conceptual engineering,

b) the train configuration to identify what size communities can receive what service,

c) an intrastate rail network analysis for several states aimed at determining the location, number and capacity of disposal sites,

d) the rate development and shipment cost analysis, and

e) the parameters of location and capacity of transfer stations within several communities considering both the availability of tracks and the local railway operating conditions.

The rail transportation analysis is highly interdependent with the work in the other project problem areas. The stability of refuse bales, for example, might determine whether or not solid waste rail cars require special spring provisions. The waste composition, volume and age-at-input plus environmental control aspects affect the operations as well as the train configuration. The organization of the shipments and the resulting costs are, naturally, a key factor in the determination of the overall feasibility of a solid waste rail-haul system.

To dimension in particular the economic feasibility and specific applicability of solid waste rail haul, the project is engaged in an analysis of the cost/performance parameters of competitive, non-rail modes of long distance waste transport. This analysis has proven to be extremely valuable for the overall system development especially with respect to the total system cost.

Exhibit IV on the following page indicates the scope of the project efforts concerning the rail transport building block of the system. The Exhibit shows the many factors which need consideration and which might be significant in determining the feasibility of solid waste rail haul. Again, all the items indicated do not receive an equal amount of staff attention.

6. Sanitary Landfill Disposal in Conjunction with the Rail Haul of Solid Wastes

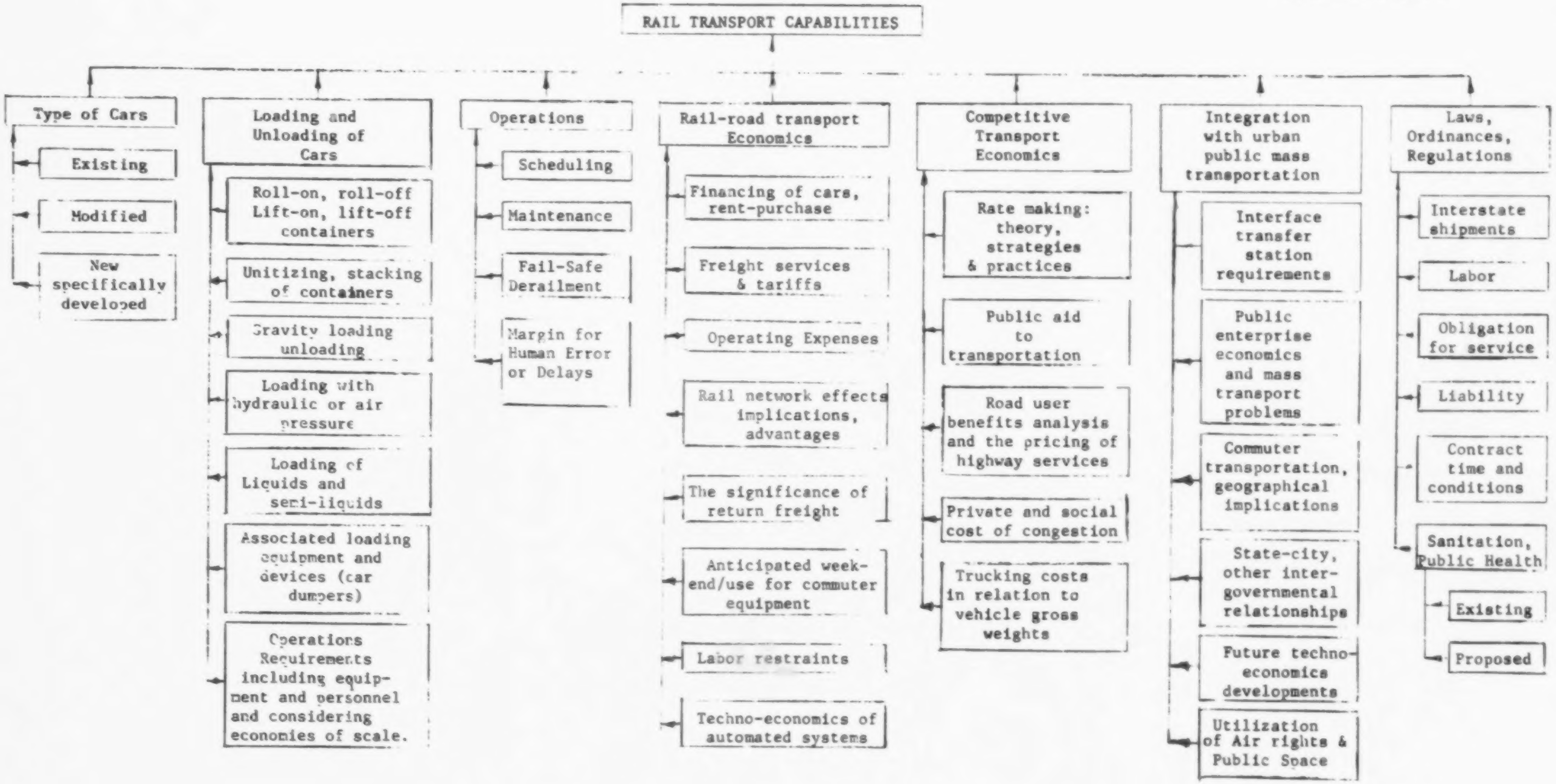
The waste disposal connected with rail-haul systems differs from the commonly known sanitary landfilling primarily in the scale of the operations. In addition, rail haul could provide access to active strip mines and thus open up heretofore not used disposal opportunities. In this way the system might provide positive community benefits through a land reclamation program.

The possibilities of waste disposal through active strip mine operations are investigated in some detail. It appears that an integration of strip mine operations with the disposal efforts will facilitate a desirable reduction in the disposal cost.

The associated studies on the cost/performance capabilities of strip mining equipment have proven, simultaneously, to be of value for the conceptualization of large scale disposal operations in other than active strip mine landfills. Some of the equipment, for example, might be used in the reworking of abandoned strip mines and thus enable solid waste rail haul to aid in the reclamation of wastelands in a self-sustaining way.

EXHIBIT IV

APWA SOLID-WASTE-
RAIL-HAUL PROJECT


RAIL TRANSPORT CAPABILITIES
Type of Cars
Existing
Modified
New specifically developed
Loading and Unloading of Cars
Roll-on, roll-off Lift-on, lift-off containers
Unitizing, stacking of containers
Gravity loading unloading
Loading with hydraulic or air pressure
Loading of Liquids and semi-liquids
Associated loading equipment and devices (car dumpers)
Operations Requirements including equipment and personnel and considering economies of scale.
Operations
Scheduling
Maintenance
Fail-Safe Derailment
Margin for Human Error or Delays
Rail-road transport Economics
Financing of cars, rent-purchase
Freight services & tariffs
Operating Expenses
Rail network effects implications, advantages
The significance of return freight
Anticipated week-end/use for commuter equipment
Labor restraints
Techno-economics of automated systems
Competitive Transport Economics
Rate making: theory, strategies & practices
Public aid to transportation
Road user benefits analysis and the pricing of highway services
Private and social cost of congestion
Trucking costs in relation to vehicle gross weights
Integration with urban public mass transportation
Interface transfer station requirements
Public enterprise economics and mass transport problems
Commuter transportation, geographical implications
State-city, other inter-governmental relationships
Future techno-economics developments
Utilization of Air rights & Public Space
Laws, Ordinances, Regulations
Interstate shipments
Labor
Obligation for service
Liability
Contract time and conditions
Sanitation, Public Health
Existing
Proposed

7. The Organizational, Financial and Legal Implementation of Transporting Solid Wastes by Rail

The execution of solid waste rail-haul operations requires cooperation between local and state governments and private enterprise. To identify the execution alternatives, it is necessary to investigate

a) the functions state and local governments might perform within a solid waste rail-haul system, and

b) the contract elements arising from the very nature and requirements of the system itself.

The project efforts in this problem area are mainly carried out through a workshop for state officials and a community workshop for the public agencies participating in this study. Both workshops are designed to provide the inputs officials need in deciding for or against the use of solid waste rail haul. Among other objectives (e.g., the development of a rail-haul guide book for local officials) the community workshop aims at the establishment of a solid waste rail-haul community typology.

The first of the three community workshop sessions has already been held. The remaining two sessions, as well as the workshop for state officials, are planned to be scheduled at a time when those in attendance can observe the operations of the refuse compression test program.

In the overall, the feasibility of the total solid waste rail-haul system is based upon the techno-economic feasibility of its individual building blocks such as transfer stations and disposal operations. Lack of technical or economic feasibility in any link of the chain will result in there being no chain at all. Thus, this project requires several individual feasibility studies be conducted in a well integrated way in order to achieve the project objectives.

CHAPTER FIVE - CRITERIA FOR EVALUATING RAIL HAUL OF SOLID WASTES

To enable a rational choice from a large variety of possible system elements and their combinations, it is necessary to fashion first a clear statement of objectives and evaluation criteria.

Accordingly, the study team has constructed the following guide which is designed to serve the needs and the best interests of the public at large. This guide also takes into account the concern of individual groups or institutions which could be involved in the operations of a solid waste rail-haul system. Examples include public health authorities and public works officials in the various areas a system is to serve. To facilitate a comparative systems analyses, the criteria are also intended for use in the evaluation of any proposed or existing solid waste disposal system.

The criteria address themselves to the characteristics of an ideal system. To judge the suitability of a given system all criteria need not be met simultaneously. To guide the developmental efforts along the most productive avenues, it is necessary to consider the criteria combination in terms of an overall optimization.

The characteristics of an ideal solid waste disposal system can be identified as follows:

I. SOLID WASTE MATERIALS

The system should be capable of handling

... as great a variety as possible of the solid waste materials generated by residents, municipalities, commerce and industry,

... irrespective, as far as possible, of material composition, condition (wet or dry), age or unit size.

II. SOLID WASTE VOLUMES

The system should be capable of accommodating

... large and small input loads without undue sacrifice of effectiveness,

... sudden surges without appreciable disruption,

... seasonal fluctuations, and a

... gradual increase or decrease in the workload.

III. PUBLIC HEALTH AND ENVIRONMENTAL CONTROL

The system should

... function without polluting water, air and land,

... at least meet any existing public health and environmental control standards,

... be nuisance-free with respect to noise, dust, odor and unsightliness,

... be safe with respect to occupational hygiene and to operations for both the people involved and the public served, and

... be aesthetically pleasing to the public which has to support and watch it.

IV. RELIABILITY OF OPERATIONS

The system should

... function effectively regardless of climate or weather conditions,

... be immune to disruption by damage to some part of the system,

... use proven elements and practices, and

... be resilient under catastrophic conditions.

V. SCOPE OF SERVICE

The system should be capable of serving

... relatively small and large communities,

... as many communities simultaneously as possible and do both

... irrespective, as far as possible, of differences in local situations.

VI. ECONOMICS

The system should be competitive with other systems in respect to

... the total cost including investment, operations and maintenance,

... the amount of savings produced for the local collection effort,

... a rapid cutback in costs if the load is reduced irrespective of whether temporary or permanent,

... the attraction it may hold for private enterprise, especially the railroads, and

... the overall economic impact on a given area.

VII. ORGANIZATION

The system should

... have organizational simplicity,

... offer potential users many options in terms of management and execution, and

... adapt to user needs as much as possible and not vice versa.

VIII. IMPLEMENTATION

The system should

- ... be publicly acceptable,
- ... be rapidly adoptable by municipalities, commercial collection and disposal firms, self-disposers, especially those in industry, and by railroads,
- ... be open to and stimulate progress in terms of a product, process or method evolution, and
- ... hold promise for side benefits such as salvage or land reclamation.

The degree to which any existing or proposed solid waste disposal system meets these criteria can be taken as a measure of its relative merit. It is, of course, recognized that no ideal waste disposal system exists which meets all of these criteria to the fullest extent possible. Thus, any system evaluation, selection or development must emphasize optimization in terms of the respective cost performance parameters.

CHAPTER SIX - COMPOSITION AND VOLUMES OF SOLID WASTES

It is well known that solid wastes contain a large number of different types of solid products, each of which is made up of a variety of different chemical compounds and elements. Furthermore, solid wastes also contain, in many cases, liquids which are introduced into the wastes either as part of the waste product such as food wastes, or by absorption from the surrounding atmosphere or as a result of spillage. It is also well known that the composition of the individual lots of solid wastes with respect to the types and amounts of solids and moisture can vary appreciably.

A description of the general composition, specific constituents and properties, and volumes of wastes is given in the following paragraphs. In addition, the relevance of composition, volumes and unit sizes, and the influence of salvage on the rail-haul system are discussed.

I. THE GENERAL COMPOSITION OF WASTES

There are several major sources from which wastes originate. These can be broadly subdivided into residential, municipal, commercial, industrial and agricultural. Although many types of wastes, such as packaging, can be found in any given source, the items and the quantity of specific types of wastes in different sources vary appreciably.

1. Residential Wastes

Residential wastes contain a great variety of manufactured and natural products discarded by households. Most of the items are relatively small in size; however households do discard oversized wastes such as furniture, refrigerators and large appliances.

Accurate data about the composition of wastes are not available. However, a number of estimates have been published about the composition of residential wastes with respect to types and amounts of the various components. These data, based on the average yearly composition and percentage of different types, by weight, are given in the following table.

Table 1. COMPOSITION OF RESIDENTIAL WASTES
(Estimated United States Average Per Year)

Type	Weight-Percentage of Total Wastes
Paper Wastes	60.0%
Food Wastes (bound water and solids)	8.5
Glass and Ceramic Wastes	8.0
Metallic Wastes	8.0
Plants and Grass (bound water and solids)	6.5
Plastic Wastes	3.5
Furniture and Boxes	1.5
Construction Wastes	1.0
Textiles	0.5
Dirt and Vacuum Cleaner Catch	0.5
Rubber Wastes	0.4
Leather Wastes	0.4
Household and Garden Chemicals (solids, liquids)	0.4
Paints, Oils and Varnishes	0.3
Miscellaneous (liquids, special wastes, micro-organisms, etc.)	0.5

It should be emphasized that the values given are only estimates and not actual measured values, and that the composition of residential wastes and other wastes vary with region, climate and season.

The variations in composition due to regional, climatic and seasonal influences can be quite significant. The effect of seasonal influences on a few wastes to be compared to the averages presented in the previous table, is shown as follows:

SEASONAL DAILY MAXIMA OF SOME RESIDENTIAL SOLID WASTES

Type	Weight-Percentage of Total Wastes (estimated maxima per day)
Food Wastes	20%
Plants and Grass	35
Paints, Oils and Varnishes	2

In addition to the changes in composition indicated above, it should be kept in mind that even larger variations are to be expected with individual truck loads of wastes. These can contain up to 100 percent of one type of waste product such as paper, garden wastes and discarded food.

2. Municipal Wastes

Municipal wastes are generally composed of the same type of materials with respect to their chemical nature as those found in residential wastes. However, these wastes contain an appreciably higher amount of oversized items such as abandoned cars, trucks, wooden logs and unusual wastes such as dead animals. They also might contain a high amount of demolition wastes and include incinerator ashes, sludge from sewage treatment plants and dirt from street sweepings. Loads of wastes collected from parks sometimes contain garden wastes almost exclusively.

3. Commercial Wastes

Commercial wastes originate mainly in offices, stores, theaters, markets and also in hospitals, clinics, and parks. They usually contain a large amount of packaging materials and food discards, similar to those found in residential and municipal wastes.

Hospitals and clinics also discard these types of wastes. However, they also generate hazardous chemical and pathological wastes which can represent health hazards.

4. Industrial Solid Wastes

Industrial solid wastes include a large variety of organic and inorganic wastes. They contain in all cases packaging materials which can be oversized and of heavy construction. In addition to wastes produced by offices and cafeterias, the waste types generated are related to the particular process and product manufactured. A brief description of specific waste types associated with a few industries are given below:

Table 2. INDUSTRIAL WASTES

Industry	Composition (Process Wastes)
Paper	Sawdust, dust from rag stock, lime sludge, black carbon residue, paper rejects.
Fruit and Vegetable	Scraps of fruit and vegetables, seeds, cobs, oils, processing chemicals.
Meat and Poultry	Flesh, entrails, hair, feathers, fat, bones, blood, grease.
Dairy	Butterfat, milk solids, ash, acids, discarded milk and cheese.

Table 2. INDUSTRIAL WASTES
(Continued)

Industry	Composition (Process Wastes)
Glass and Ceramics	Broken ceramics, some glass, sludges, dusts, chemicals, abrasives.
Metallurgical	Emulsified cleaners, machine oils, oily sludge, borings and trimmings, toxic chemicals.
Iron Foundries	Cupola slag, iron dust.
Plastics	Scraps from molding and extrusion, rejects, chemicals.
Textiles	Textile fibers (plastic and natural), rags, processing chemicals, detergents.
Construction (including remodeling and demolition)	Sand, cement, brick, masonry, metal, ceramics, plastics, glass.
Chemical	Organic and inorganic chemicals and rejects of synthetic products such as fibers, rubbers, pigments; can contain toxic, explosive and radioactive wastes.
Lumber and Furniture	Sawdust, wood chips, abrasives, oily rags, upholstery materials, paints, varnishes, scraps of wood, plastics and textiles.

5. Agricultural Wastes

Agricultural wastes derived from farms and ranches also contain similar waste products as residential and commercial wastes. However, the composition is affected by the large proportion of organic wastes from field and seed crops, vegetable crops and prunings. They also contain manure, dead animals, meat scraps, hair and feathers.

Agricultural solid wastes are excluded from the investigation in the present study because they do not occur primarily in the densely settled urban areas. All the other types of waste are being analyzed with respect to their acceptability in a solid waste rail-haul system.

II. SPECIFIC CONSTITUENTS AND PROPERTIES OF WASTES

General information about the composition of broad categories of waste products has been presented in the previous pages. However, general knowledge of this type does not provide sufficient background information about the physical, chemical and biological properties of wastes. In order to gain a better insight into waste properties and to enable the evaluation of their impact on specific system elements such as processing, public health, transport and landfill, a more detailed analysis of waste constituents is being undertaken. The information gathered is being compiled into a series of tables and will be presented in full at a later stage.

The tables contain listings of manufactured and natural products found in solid wastes and their chemical constituents. They also contain information on the structure of the constituents and factors such as degradation and decomposition products and toxicity where available.

A few examples of the information being developed is given in Tables 3, 4, and 5. These tables were selected as exhibits since they define waste types which warrant special attention in this study. Table 3 contains information about the composition and some properties of paper products which constitute a major part of solid wastes. Table 4 identifies the chemical constituents and the high water content of food wastes which are a source of nutrients for microorganisms and which, due to their high water content, introduce some problems in compaction processing. Table 5 shows the chemical and physical structure of rubbers and the toxicity of some elements as well as molecular fragments which affect processing and can be a pollution hazard.

Table 3. PAPER WASTES

Type of Paper	Major Constituent $(C_6H_{10}O_5)_x$ *	Other Constituents	Fillers, Binders and Coatings	Ash**	Decomposition of Cellulose[3]	
					Heat	Bacterial in soil
Newspapers	α -Cellulose	Lignin Hemi-Cellulose Pentosans	Rosin Alum Casein	3.5%	Carbon Acetic Acid Methyl Alcohol Acetone Furfural CO, CO_2 Carcinogenic*** Compounds	H_2 CH_4 CO_2 Fatty Acids
Brown Kraft Paper	α -Cellulose	Lignin Hemi-Cellulose Pentosans	Gum, Starch Clay, Rosin Alum, Resin	6.5%		
Corrugated Boxes	α - Cellulose	Lignin Pentosans β & γ Cellulose Hemi-Cellulose	Clay, Starch Glue TiO_2	7.8%		
Books and Magazines	α -Cellulose	β & γ Cellulose Lignin	Clay, Starch Rosin, Casein TiO_2, $CaCO_3$ Satin White	28.0%		
Writing Papers	α -Cellulose	β & γ Cellulose Hemi-Cellulose Lignin Pentosans	Rosin, Clay Alum, Starch Satin White Resin			
Glassine & Grease Papers	α -Cellulose	Hemi-Cellulose Lignin Pentosans β & γ Cellulose	Glycerine Clay, Starch Wax	6.0%		
Tissue Papers	α - Cellulose	Lignin, Pentosans	Starch	0.7%		
Paper Food Containers	α - Cellulose	Lignin Hemi-Cellulose β & γ Cellulose Pentosans	Rosin, Clay Starch, Alum Wax	7.8%		
Paper Boards	α - Cellulose	Lignin, Pentosans Hemi-Cellulose	Clay, Rosin, Wax Starch, Resin	7.5%		

Sources: 1. Ralph W. Komler, "Varieties of Paper and PaperBoard," Waste Paper Utilization Council
2. James P. Casey, "Pulp & Paper," Vol. I to III, Interscience Publishers, Inc., New York
3. E. Sutermeister," Chemistry of Pulp and Papermaking, John Wiley, 1920
* condensed formula of cellulose fiber
** average values
*** most organic substances can produce carcinogenics which can cause Cancer.

Table 4. FOOD WASTES

	CHEMICAL COMPOSITION							
	ORGANIC				INORGANIC			
Food Type	Proteins $(-R-CO-$ $-NH-R')_n$	Fat H CO-COR HCO-COR' HCO-COR" H	Carbo-hydrates CH_2OH- $-(HC-OH)_n-$ CHO	Vitamins A, B, C	Water	Mineral Matter Major Constituents	Ash	Example
Dairy Products[1]	0.5 to 3.3%	3.6 to 12.8%	0	Trace	15.0 to 88%	Calcium	0.72 to 0.76%	Milk, Butter, Cheese
Fish[2]	14.2 to 22.9%	0.3 to 12.8%	0 or Trace	Trace	64.6 to 84.2T	Calcium Phosphorus	1.0 to 1.7%	Cod, Perch Trout, White Fish
Fruit[3]	0.3 to 1.0%	0	3.5 to 14.9%	Trace	65.0 to 94.9%	Potassium, Iron, Phosphorus, Copper, Manganese	0.3 to 0.6%	Apples, Grapes, Oranges, Peaches
Meat and Meat Products[4]	2.2 to 28.8%	1.2 to 92.8%	0 to 5.0%	Trace	40.0 to 75.0%	Sodium, Chlorine	0.2 to 7.3%	Beef, Pork, Lamb
Vegetables[5]	1.0 to 6.7%	0.1 to 1.2%	2.9 to 27.9%	Trace	68.5 to 95.4%	Calcium, Iron, Phosphorus	0.58 to 1.53%	Beans, Potato, Carrot, Spinach
Breakfast Cereals[6]	6.3 to 15.5%	0.2 to 2.4%	71.0 to 83.0%	Trace	4.3 to 10.4%	Calcium, Iron Phosphorus	0.4 to 4.2%	Corn Flakes, Puffed Rice
Cereal Grains[7]	9.9 to 12.4%	1.7 to 8.6%	62.3 to 71.9%	Trace	8.4 to 12.2%	Calcium, Iron Phosphorus	1.7 to 2.4%	Wheat, Corn, Rye, Barley

1. Gerrard, "Meat Technology," London, 1951, p. 282.
2. Jacobs, "The Chemical Analysis of Food and Food Products," New York, 1951, p.676.
3. Blanck, "Handbook of Food and Agriculture," New York 1955, pp 561-63.
4. Gerrard, pp. 289-90.
5. Jacobs, pp559-60.
6. Kent-Jones and Amos, "Modern Cereal Chemistry," Liverpool, 1957, p. 388.
7. Jacobs, p. 498.

TABLE 5 : RUBBERS

Chemical Composition				Toxic and Corrosive Elements & Molecular Fragments
Synthetic[1]		*Natural[2]		
Butadiene Polymers	$-CH_2CH:CHCH_2CH_2CH:CHCH_2-$	Rubber Hydrocarbons	93.30%	
Chloroprene Polymers	$-CH_2CCL:CHCH_2-$	Fatty Acids, Sterols & Esters	2.89	
Organic Polysulfides	$-CH_2CH_2OCH_2OCH_2CH_2CH_2SS-$	Protein-Amino Acids	2.82	Chlorine Sulfur Cyanides Amides Carcinogenics
Plasticized Vinylchloride	$-CH_2-CCL_2-$	Inorganic Salts	0.38	
Butadiene + Styrene	$-CH_2CH:CH(CH_2)_2CHC_2H_5CH_2CH:CHCH_2-$	Moisture	0.61	
Butadiene + Acrylonitrile	$-CH_2CH:CHCH_2CH_2CHCN-$			
Tetrasulfide-ethylene dichloride	$-CH_2CH_2S_4-$			
Isobutylene + Isoprene	$-C(CH_3)_2CH_2CH_2CCH_3:CHCH_2C(CH_3)_2-$			
Isobutylene + Butadiene	$-C(CH_3)_2CH_2CH_2CCH_3:CHCH_2C(CH_3)_2-$			
Isobutane Polymers	$-CH_2CHCH_3CH_2-$			

* (% by weight)

Ref: 1. R. N. Shreve, "Chemical Process Industries", McGraw-Hill, 1967.

2. J. A. Kent, "Industrial Chemistry", Reinhold Publishing Corporation, New York, 1962.

The chemical constituents and properties of other waste types will be covered in additional tables. These will contain information about the following items:

> Grass, Wood and Plants; Glasses and Ceramics; Metals and Alloys; Textiles; Plastics; Construction Wastes; Furniture and Fixtures; Leather; Paints, Oils and Varnishes; Dirt and Vacuum Cleaner Catch; and Household Chemicals.

The properties of waste constituents have to be considered carefully when dealing with different waste mixtures. It is clear that wastes made up primarily of one type of waste product exhibit different properties than those composed of equal concentrations of different products.

III. THE VOLUMES OF SOLID WASTES IN RAIL HAUL SYSTEMS

The overall volume of solid wastes generated in the United States is estimated to range upwards of about 185 million tons per year. Also it is often estimated that in the densely settled urban areas solid wastes are generated at a rate of roughly one ton per capita per year.

The solid waste rail-haul volumes must, of course, be determined in terms of the communities that might utilize the system. Specifically, it is important to dimension the potential annual tonnages as well as the potential daily shipment volumes and their fluctuations.

1. Potential Annual System Tonnages

In the overall, the potential market for solid waste rail haul might be quite large. This can be gauged by the number of people living in the relatively densely settled metropolitan areas which, of course, are all served by railroads. Based, for example, on the service area of one large railroad system, in this case the Penn Central railroad, the potential market at a waste generation rate of one ton per capita per year, can be dimensioned as follows:

STATE POPULATION LIVING IN STANDARD METROPOLITAN STATISTICAL AREAS SERVED BY A LARGE RAILROAD SYSTEM

		POPULATION LIVING IN SMSA			
		Served/Penn Central		Not Served/Penn Central	
STATE	State (Total) POPULATION	Population	% of State Total	Population	% of State Total
Illinois	10,775,300	7,682,300	71.3	770,900	7.1
Indiana	4,958,400	3,400,900	68.6		
Kentucky	3,164,500	796,300	25.2	368,300	11.6
Maryland-D.C.	6,241,100	4,804,900	77.0		
Massachusetts	5,424,500	4,530,000	83.5	734,000	13.5
Michigan	8,392,100	6,190,600	73.8	588,800	7.0
Missouri	4,516,000	2,282,700	50.5	1,572,400	34.8
New Jersey	6,910,700	3,511,700	50.8	2,045,100	29.6
New York	18,101,700	16,224,800	89.6	304,500	1.7
Ohio	10,537,200	8,747,300	83.0	82,600	0.8
Pennsylvania	11,711,400	9,922,800	84.8	746,300	6.4
West Virginia	1,771,600	514,300	29.0	211,900	12.0
	92,504,500	68,619,600	74.2	7,424,800	8.0

Source: U. S. Bureau of the Census, Sales Management Magazine Railroad Guide

The above data suggest that, if all solid wastes from these metropolitan areas would be handled by one solid waste rail-haul system, the annual tonnage would amount to more than 68 million tons. In broad averages, this is the equivalent of more than 1.3 million tons per week and of about 264,000 tons per day calculated at 260 working days per year.

It should be highlighted, however, that the data indicate only a general order of magnitude of the solid waste volume which potentially might be handled by a rail-haul system.

The calculations, for example, assume that the amount of self-disposal is negligible or that it would become negligible due to the attractiveness of solid waste rail haul. But even if the indicated amounts of solid waste would be reduced significantly, the tonnages still left for solid waste rail haul would remain substantial.

2. Daily Shipment Volumes from Individual System Areas

The daily solid waste shipment volumes from individual system areas vary with both the number of people living in a given area and the number of operating days per week. This is indicated in the following table which correlates the area population with the daily shipment volume prorated on a five, five and one-half, and six, working day week.

THE ORDER OF MAGNITUDE IN THE VOLUME OF DAILY SOLID WASTE SHIPMENTS

BROKEN DOWN BY POPULATION, SIZE OF AREA AND NUMBER OF WORKING DAYS PER WEEK

Area Population	Annual Tonnage at One Ton per Capita per Year (tons)	Daily Shipment Tonnage* at Working Days per Week		
		5 days (tons)	5-1/2 days (tons)	6 days (tons)
10,000	10,000	38.5	35.0	32.0
25,000	25,000	96.1	87.4	80.1
50,000	50,000	192.3	174.8	160.2
100,000	100,000	384.6	349.6	320.5
300,000	300,000	1,153.9	1,049.0	961.5
500,000	500,000	1,923.1	1,748.3	1,602.6
800,000	800,000	3,076.9	2,797.2	2,564.1
1,000,000	1,000,000	3,846.2	3,496.5	3,205.1
3,000,000	3,000,000	11,538.5	10,489.5	9,615.4
5,000,000	5,000,000	19,230.8	17,482.5	16,025.6
8,000,000	8,000,000	30,769.2	27,972.0	25,641.0

* Data are slightly rounded

It should be emphasized that the above data present only rough benchmarks for the initial conceptualization of the system. Seasonal variations, for example, might increase the weekly volume by 15 to 30 percent during the summer and cause a corresponding decrease during the winter.

Furthermore, the daily variations in the amounts of solid waste collected may even exceed the seasonal variations. If the wastes are collected on a once-per-week schedule, the daily amounts tend to vary little and reflect only the seasonal influences. However, if the wastes are collected on a more than once-per-week schedule, the daily amounts might vary by as much as 50 percent of the daily average calculated on a per week basis.

IV. THE RELEVANCE OF COMPOSITION, VOLUMES AND UNIT SIZE OF WASTES IN THE RAIL-HAUL SYSTEM

The relative importance of composition and associated properties, and the volumes and unit size of wastes can be best understood by evaluating their effect on different system elements such as processing, public health, transport and landfilling.

In any given processing operation it is necessary to establish the physical and chemical composition of the materials and the volumes to be processed. For example, in chemical processing the solubility of waste components has to be known. The major constituent of paper products, which also constitute the major portion of residential wastes, is α-cellulose. This constituent is insoluble in water and in cold alkalies and only partially soluble in dilute acids. Thus, other solvents have to be used if the major part of paper is to be dissolved.

In physical processes, such as size reduction and compaction, it is essential to establish the physical properties of the materials to be processed. Materials, such as paper, plastics and rubbers (see Tables 3 and 5) are made up of long-chain molecules which exhibit fiber structures and elastic properties. As a result, these materials can be reduced in size best by a tearing action along the fiber and by cutting across the fibers. In compaction, the fiber structure of such materials poses some problems. Bending of fibers during compaction results in the tendency of the fibers to spring back, an effect which has been observed in the compaction of waste products containing paper, rubbers and some plastics.

In addition to considerations based on the physical properties of chemical constituents in wastes, processing operations also require a knowledge of the physical sizes and volumes which have to be handled. Both the physical size of the wastes and the volume govern the development of material handling operations, process feeding devices, and the general process and system layout.

The composition of wastes and the concentration of specific waste constituents also have a large effect both on public health and the environment. In order to survive, the majority of bacteria and fungi must have organic food in their diet. Organic compounds such as proteins, carbohydrates and vitamins found in food wastes (see Table 4) are the primary source of nutrients for pathogens and other microorganisms. The water content of wastes affects the bacterial activity through which organic molecules are degraded; the final degradation products being gases such as CH_4, CO, CO_2, H_2S, and others.

Other rail-haul system elements are also affected by the volumes and the composition of wastes. These include transport and landfill. Large volumes affect not only the physical elements of these two operations but also the concentration of waste constituents in a restricted space. Depending on the nature of the constituents, they could introduce environmental difficulties both during transport and in landfills.

It should be emphasized that the solid waste rail haul, being a mass disposal system, necessitates the evaluation of effects arising from specific types of wastes, and from the high concentrations of these wastes. These effects, of course, have to be considered with respect to all system elements.

V. INFLUENCE OF SALVAGE ON COMPOSITION AND VOLUMES OF WASTES

The influence of salvage on the composition and volumes of wastes could be appreciable. However, the magnitude of its effect depends on the type of material removed and its quantity in the waste.

For example, if 50 percent of the total waste products should be removed from residential wastes, the remaining wastes would constitute only one-half of the total wastes discarded annually. This would mean that only 50 percent of residential wastes have to be transported, and the requirements with respect to landfill space would be substantially decreased. On the other hand, salvage operations might be performed on the landfill site and the associated transport cost would occur.

The effect of the removal of such a large proportion of one type of wastes such as paper wastes would also affect the composition of the wastes appreciably. The wastes would now contain a double percentage in weight of all other constituents. Food, glass and ceramics and metallics which were estimated to constitute about 8.5, 8.0 and 8.0 percent of the total weight of residential wastes (see Table 1) would increase to 17.0, 16.0, and 16.0 weight percentage, respectively. This would also mean that the properties of the wastes would change. This, in turn, would affect the methods of processing and transport; and the environmental and cost factors of waste disposal.

CHAPTER SEVEN - TRANSFER STATIONS FOR RAIL HAUL OF SOLID WASTES

Transfer stations are needed in virtually all solid waste rail-haul systems. They represent the first building block of the operations. Their function is to receive the wastes from the collection trucks, to provide for any processing necessary and for the transfer of the materials to the rail cars.

This Chapter deals in a preliminary way with the types and sizes of transfer stations, their physical interface with the local collections, on solid waste processing, the solid waste compaction test program, and on material handling elements.

I. THE TYPES AND SIZES OF TRANSFER STATIONS

To satisfy the demands for various types of transfer stations, the project is engaged in analyzing and developing design concepts for stations with performance ratings of 50, 100, 250, 500, 1000 and 2000 tons per eight-hour shift. As suggested by the data presented in Section III, Chapter Six, a 50 ton transfer station appears to be sufficient to service an area containing about 15,000 people while a 2000 ton station can service an area of about 500,000 people.

The specific applicability of the various sizes and kinds of transfer stations is being analyzed and determined through the community workshop which is conducted for the public agencies participating in this project. This approach has been chosen since it focuses on actual local conditions and therefore, facilitates the development of more tailor-made concepts. Factors such as the following exemplify some of the items considered in this work:

a) the types and amounts of solid wastes generated in the various sections of a community, e.g., industrial parks versus residential areas versus commercial centers,
b) future community development and solid waste generation patterns,
c) the structure of the local public and private collection effort, i.e., type and capacity of vehicles, collection routes and collection schedules, and
d) the identification of desirable transfer station service areas with respect to potential transfer station functions.

As a result of these efforts, it is intended to determine the capacities most desired for individual transfer stations as well as their specific functions within a transfer station network. In terms of function, the transfer stations might be classified as heavy duty, standard, and/or special purpose stations.

The types and sizes of transfer stations are, of course, directly interdependent with factors concerning the spatial location of stations within a local solid waste removal effort. It should be highlighted that all stations need not be located necessarily on rail tracks. It is conceivable to justify ancillary stations, i.e., those not located on rails, by the savings they might produce for a given collection effort.

The capacity of the transfer stations is initially pegged to one eight-hour shift on purpose. This allows for the scheduling of overtime as needed in order to accommodate effectively the potential daily as well as seasonal fluctuations in the waste delivery. Simultaneously, it tends to facilitate a speedy, i.e., daily, removal of the waste materials. In addition, the initial one-shift operating arrangement provides flexibility with respect to both the acceptance of solid wastes now self-disposed of and which might be attracted to the system as well as the increasing needs of the future.

In the over-all, seven basic transfer station layout concepts have been identified thus far and are being worked on. These concepts can be described briefly as follows:

1. a circular transfer station;

2. a design in which the railroad cars pass through the center of the station to permit the loading of the cars from two sides utilizing gravity loading principles,

3. a small, one-operator transfer station based on the movement of the materials by an inclined, oscillating conveyor-type solid waste handling approach,

4. an "H" pattern station in which the layout resembles the capital letter "H",

5. a compressed "T" approach in which the layout resembles the capital letter "T" with a shortened center but elongated cross bar,

6. a layout adapted to operations in incinerators to be abandoned or shutdown, and

7 a conventional transfer station design as found in several existing transfer stations.

The transfer station layout work is about 30 percent completed. The further development of the transfer station concepts is, of course, intimately related to the specific type and implementation of the solid waste processing that needs to be accommodated.

II. THE PHYSICAL INTERFACE OF TRANSFER STATIONS WITH LOCAL COLLECTIONS

The optimum design of a transfer station must take into account

a) the factors associated with the design of collection trucks, collection logistics and the unloading of the wastes,
b) the in-station process and material handling requirements, and
c) the loading of the rail cars.

The waste receiving operations represent the physical interface of a transfer station with the local collection trucks. It is at this point where the rail haul and the local collection systems meet. Thus the waste receiving operations are of key importance with respect to a smooth integration of the local collection with the solid waste rail-haul operations. Since collection truck and crew waiting time is quite expensive, collection trucks, as a rule, should not be detained for more than ten minutes by the transfer station operations.

The receiving or interface operations are, of course, determined by both the operating capacity of the transfer station as well as the net load of the collection trucks. For an average net load of 2.5 tons of solid wastes per truck, a 1000 ton transfer station, for example, would have to handle 400 truck loads per shift. If the net load per truck would increase to four tons per load, a total of 250 trucks would come in

These data, however, need to be adjusted in order to reflect realistic conditions of solid waste delivery. The trucks do not arrive at transfer stations at uniform time intervals. Sometimes as many as 30 to 50 percent of the total number might arrive within a time span of from one to two hours.

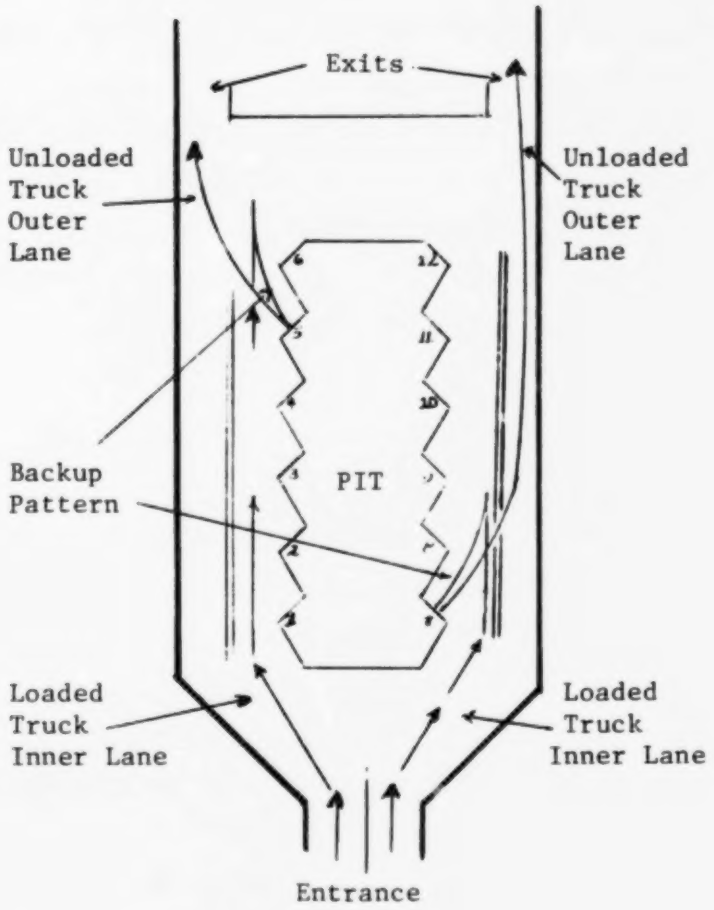
Some of the considerations to be taken into account in the conceptualization of the collection truck/transfer station interface can be illustrated by the example of the circular as well as the herringbone transfer action concept and its variations. Similar considerations apply, of course, to all transfer station analyses.

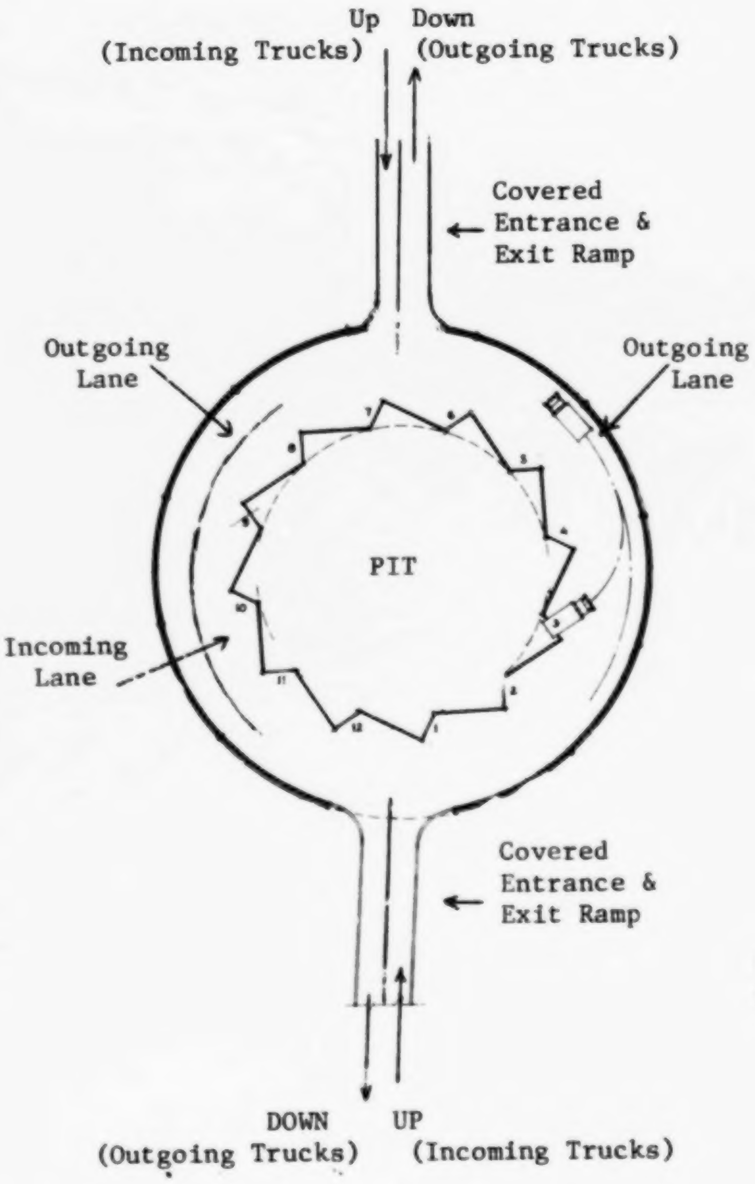
The two transfer station concepts are illustrated in Exhibit V on the following page. The circular transfer station concept, suggested in principle in 1967 by the Logemann Brothers Company, appears to represent the least flexible approach in terms of adaptation to varying capacity requirements. Due to the width of the collection trucks, this concept requires a minimum of twelve (12) dumping stalls. Most other transfer station concepts appear to be adaptable to heavy duty as well as light duty functions.

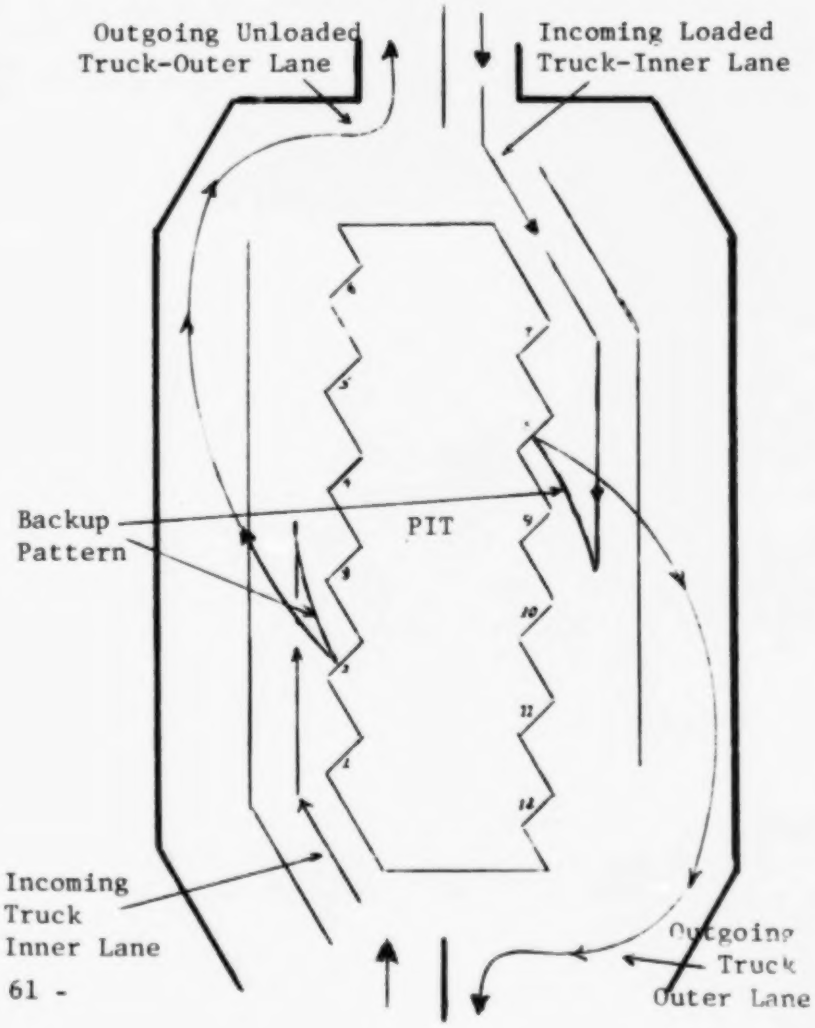
EXHIBIT V

APWA SOLID WASTE RAIL-HAUL PROJECT

INTERFACE PATTERNS COLLECTION TRUCK/TRANSFER STATION


Exits
Unloaded Truck Outer Lane
Unloaded Truck Outer Lane
Backup Pattern
PIT
Loaded Truck Inner Lane
Loaded Truck Inner Lane
Entrance


Up (Incoming Trucks)
Down (Outgoing Trucks)
Covered Entrance & Exit Ramp
Outgoing Lane
Outgoing Lane
PIT
Incoming Lane
Covered Entrance & Exit Ramp
DOWN (Outgoing Trucks)
UP (Incoming Trucks)


Outgoing Unloaded Truck-Outer Lane
Incoming Loaded Truck-Inner Lane
Backup Pattern
PIT
Incoming Truck Inner Lane
Outgoing Truck Outer Lane

If one now assumes that it takes ten minutes per truck to find a stall and dump its load, then the stations as shown in Exhibit V are capable of handling 72 trucks per hour. If the in-station time per truck could be reduced to five minutes, then the stations would accommodate 144 trucks per hour. Thus, to facilitate the in-station truck traffic flow, it is suggested that provision be made for two traffic lanes: one for the incoming, loaded trucks and the other one for the outgoing trucks.

These potential variations in the number of trucks which can be handled necessitate, in turn, that the truck entrances and exits be scaled accordingly. An arrival of 72 trucks per hour implies that every 50 seconds one truck would enter and leave a station of the capacity shown. At 144 trucks per hour this time span would be reduced to 25 seconds.

Thus the 12-stall transfer station appears to require at least two entrances and exists. With this provision it also appears likely that any truck waiting time outside the station can be kept to a minimum.

The performance capability of the collection truck/transfer station interface carries substantial implications with respect to both the conceptual design of the transfer station and the implementation in terms of equipment. This is demonstrated in the following table which correlates the net load per truck with the number of trucks handled.

CAPACITY VARIATIONS IN A 12 STALL TRANSFER STATION BASED ON VARIATIONS IN THE NET LOAD PER TRUCK

	CAPACITY VARIATIONS*			
	72 Incoming Trucks per Hour		144 Incoming Trucks per Hour	
Net Load Per Truck (Tons)	Per Hour (Tons)	Per 8-Hour Shift (Tons)	Per Hour (Tons)	Per 8-Hour Shift (Tons)
2.0	144	1,152	288	2,304
2.5	180	1,440	360	2,880
3.0	216	1,728	432	3,456
4.0	288	2,304	576	4,608
5.0	360	2,880	720	5,760

*The calculations are based on the assumption that the trucks arrive at the frequency indicated throughout the operating time of the station.

Data of the kind shown above are explorative and illustrative in character rather than definitive or perhaps practical. They might be used in this way to identify the design and performance opportunities or limitations of a given concept. In this case they dimension the range of variations which might be introduced by a given or planned collection effort. It is recognized, of course, that at present only some communities might need transfer operations of the capacities indicated in the foregoing example.

III. PROCESSING OF SOLID WASTES FOR TRANSFER INTO THE RAIL-HAUL SYSTEM

Initial information suggests that a processing of the solid wastes could provide material benefits for the implementation and execution of solid waste rail haul.

1. The Purpose of Processing

The basic purpose of processing solid waste for rail haul is

... to improve the cost/performance relationship of the overall system operations.

Specifically, the processing of the solid wastes should benefit the transport, the disposal, and the environmental control performance. Furthermore, it should facilitate the material handling as well as the storage operations that are required at various points in the system.

The case for processing the incoming solid wastes is based on the following considerations:

a) A solid waste rail-haul system should handle as great an amount and as great a variety as possible of the solid waste materials that are generated by residents, municipalities, commerce and industry.

   To reduce thus the material handling, transport and disposal requirements to manageable proportions, it appears necessary to process these highly heterogeneous wastes at least to some degree in order to obtain a more homogeneous material. To handle effectively throughout the system unprocessed items, as for example a combination of food scraps, nylons, facial tissues, oversized furniture, refrigerators and industrial crates, appears to require an overdesign of the equipment implementation and therewith unnecessary investment as well as operating costs.

b) The key to transport economics is given in the maximum utilization of the transportation equipment. This implies the need to provide for maximum payloads per unit of transport, especially if large quantities of materials are to be shipped and the economics of mass transportation are to apply.

To provide for flexibility with respect to the number of large and small communities to be served and to minimize the railroad operating restraints and therewith the transportation costs it appears desirable to utilize the existing types of rail cars most commonly available. As a result, the density/volume relationship of the materials becomes a significant factor for the system development.

Specially designed railcars are, as a rule, more expensive than standard cars. In addition, they tend to restrict any alternate utilization to a higher degree than multipurpose cars. Finally, the need for special cars might delay the application of solid waste rail haul because of the added investment required and, on the other hand, the risks which are inherent in the relatively short contract periods allowed for some communities by law. If, for example, a normally 15-year investment has to be written off within, say, five years, the cost would easily become prohibitive.

c) The landfill space needs, the associated earth moving requirements and the provision of cover material represent significant cost factors within the total system. Savings achievable by the use of processed solid wastes occupying less volume that the unprocessed wastes may amount to more than 50 percent of the cost incurred with unprocessed materials.

d) Processing, such as compaction, furthermore appears capable of inducing other favorable characteristics to the wastes besides a material densification. For example, if the solid wastes could be processed into the form of stable bales, many nuisances such as blowing paper and dust might be eliminated.

In evaluating the arguments for and against the processing of the solid wastes, it must also be recognized, of course, that the transfer of unprocessed materials, performed in accordance with environmental control standards, is not as inexpensive and convenient as it might appear. In particular, the scale of the solid waste rail-haul operations could, in some instances, introduce cost which might cause even the mere transfer of the unprocessed material to be almost as expensive as the operations of a transfer/processing station of equal capacity.

In the overall, in deliberating on the purpose of processing solid wastes for rail haul, it might be assumed, for example, that the cost for the material handling operations and the building might be roughly equal for transfer stations of the same capacity regardless of whether the materials are processed or not. Thus, only the direct process expenditures would have to be compensated for by savings in other parts of the system. Based on exploratory tests there are strong indications given that, for example, the compaction process would cost less than just the cost differential found between the shipment of unprocessed wastes and that of highly compacted materials. Additional savings of perhaps significant proportions in other parts of the system are also indicated.

2. The Processing Objective

Currently, the main objective to be accomplished by the processing operation, is the reduction in volume and increase in weight per unit of volume of the solid wastes. This can be accomplished by physical methods which can reduce or eliminate the void space which exists both at the interface between different solid materials and those present inside hollow waste items.

The reduction in volume which can be achieved, and the associated increase in weight, depends on the air-to-solid ratio of a given waste load and on the specific densities of the individual waste components. For example, if a given load is made up of solids which occupy 50 percent of the total space while the other 50 percent of the space are voids filled with air, then the maximum reduction ratio achievable would be 2:1. If, on the other hand, the volume occupied by the solid portion of the wastes would be only ten percent, and the space occupied by air 90 percent, the maximum reduction in volume achievable would be 10:1.

It should be kept in mind, therefore, that irrespective of the methods presently used, the limiting condition for volume reduction is the volume of the voids in the wastes. Only extremely rigorous methods such as compaction under enormous pressures, could lead to changes in the volume of the solid portion of the wastes. In the absence of changes in the properties of the solids, all that is accomplished is the squeezing out of the air contained in the voids.

Since the specific material properties of solids are not affected by the normal physical volume reduction methods, the specific densities of the individual materials remain the same before and after the volume reduction process. This means that if a given load initially weighs 200 pounds it will also weigh 200 pounds after the volume reduction. However, in the latter case it will occupy less space and the overall density, that is, the weight per unit of volume, will be higher.

The interrelationship between volume reduction and density increase is quite simple. If the volume is reduced by a factor of three, then the density increases by a factor of three. This simple relationship applies in all cases in which no losses of the materials occur as a result of processing.

However, since different lots of solid waste mixtures can contain materials of different specific weights, the densities of the individual lots could vary appreciably, irrespective of whether they contain the same or a different amount of void space. It is therefore conceivable that the weight per unit of volume of a given densified load of waste can be higher than that of another even if the volume reduction ratio should be much lower

The densities (pounds per cubic foot) which can be expected for densely packed solids, are close to those obtained for solid blocks of the same materials. Due to the large variations in composition of wastes, exact values of densities cannot be predicted. However useful information can be obtained by considering the overall densities of common solids found in wastes The approximate densities of some common solids are listed below.

APPROXIMATE DENSITIES OF COMMON SOLIDS AT 20°C.

SOLIDS			DENSITY RANGE (Lbs./Cubic Foot)
Papers			43 to 71
Metals:	Aluminum	(alloys)	165 " 182
	Iron	(alloys)	430 " 530
	Copper	(alloys)	500 " 550
Glasses			150 " 182
Porcelain			160 " 190
Plastics			66 " 120
Woods			12 " 71
Leathers			48 " 65
Rubbers			60 " 110
Cereals			26 " 48
Fats			57 " 61
Wool			50 " 82
Masonries			100 " 162
Bricks			88 " 125
Cements			100 " 144

It can be seen from the table that the average density of very dense bales, if made up solely from paper wastes, could be approximately 57 pounds per cubic foot. The density of steel scrap on the other hand, could have a density of 480 pounds per cubic foot. However, it should be remembered that such densities can only be expected if all the voids in the bale are eliminated.

In the absence of voids, mixtures of wastes containing a variety of different materials in different proportions should have densities which are between the minimum and maximum values indicated in the table. They could, for example, lie in the vicinity of about 80 pounds per cubic foot for certain mixtures of wastes.

So far, consideration has been only given to the contribution of the solid portion of wastes to the densities achievable if all or nearly all of the voids are eliminated from the wastes. However, the overall density of the waste mixture is also affected by the liquid content in it.

In the absence of any swelling, the moisture absorbed by the solids does not produce a measurable increase in the volume of the solids and therefore only adds to their weight. The weight of the moisture contained in refuse, however, could be very high. It is, for example, conceivable that the contribution of moisture to the weight per unit of volume could be higher than 50 percent. Such a contribution will be especially noticeable if the wastes contain a high proportion of highly absorbent materials such as paper and textiles. Materials such as metals have little or no tendency to absorb moisture and therefore increases in densities due to the presence of liquids are not encountered if the wastes would contain only metal.

It can be concluded that the decrease in volume which could be achieved by a volume reduction process, will depend on the air-to-solid ratio in the waste. Since this ratio is likely to vary from load to load, different values are to be expected for individual waste mixtures. Current estimates of volume reduction achievable for waste mixtures range from about 3:1 to 10:1.

If a single load of wastes is considered, the increase in density after volume reduction would be proportional to the decrease in volume. However, different types of wastes reduced in volume by the same amount do rarely have the same weight per unit of volume. Equal weights can only be expected if, after reduction, the materials contained in the same amount of space have the same specific densities.

Under optimum conditions of processing by which all voids in the wastes could be eliminated, and the wastes contain only solids, the densities achievable range from about 57 pounds for paper to about 480 pounds for iron scrap per cubic foot. However, if the processing method is not capable of eliminating all of the void spaces then the ultimate density would be proportionally less. For example, the weight of paper wastes containing 50 percent of void space would be about 28.5 pounds per cubic foot.

If the wastes contain absorbed moisture in addition to solids, the density value measured would reflect the contribution of the liquid to the total weight. This contribution can be appreciable, both for processed and unprocessed wastes. However, it would not affect the volume of the densified wastes.

3. Processing Methods

There are different methods which could be used to reduce the volume and thereby increase the density of solid wastes. Recently, two methods have gained special attention. These are size reduction and compaction of waste materials in presses. In order to determine their applicability and limitations both methods are described in some detail in the next sections.

a) Size Reduction

Size reduction is discussed in terms of its technical implications and costs.

aa) Technical Considerations

Size reduction has been applied to solid wastes, in a limited way, primarily as a pre-processing method. It has been utilized in salvaging and composting operations to reduce the size of bulky items. It has also been used occasionally as a pre-processing method in incineration to facilitate combustion by increasing the surface area of organic wastes. More recently, size reduction has been utilized as a means to decrease the volume of existing voids in wastes.

It should be recognized that size reduction is not in principle a method of volume reduction, and that a reduction in volume of compact solids such as logs or metal bars cannot be achieved by its application. In fact such items, when shredded, occupy an appreciably larger space than originally due to the introduction of voids not present initially in the compact materials.

Solid wastes, however, do not contain only compact solid items, but also a high proportion of products which can contain large voids. A decrease in volume can be achieved therefore by breaking up waste items such as large containers. It should be pointed out, however, that in no case can size reduction provide a means to eliminate all voids from wastes or any other materials. Since the ultimate volume reduction of wastes by size reduction methods is limited, other aspects of the process have to be considered to determine its applicability to the rail haul of solid wastes.

To determine the technical applicability and limitation of size reduction methods to solid wastes, a separate study is undertaken. This study, which will be reported upon at a later stage, includes sections on the principles of size reduction, general machinery, equipment thus far used for solid wastes, problems encountered in size reduction of wastes, and the advantages with respect to material handling and landfilling of disintegrated wastes.

It was found to date in this study that a fully comprehensive theory of size reduction has not yet been developed and that the principles by which different solids disintegrate are poorly understood. As a result, most of the equipment on the market has a high power requirement with most of the power being dissipated as waste energy, rather than being utilized as disintegration energy. In addition, it is found that many different types of equipment, based on different principles, have been used to accommodate specific property requirements even for relatively homogeneous materials.

The high degree of heterogeneity of wastes, both with respect to individual items and different items in the mixtures, poses a difficult problem. In the development of suitable size reduction equipment, it is therefore essential that the disintegration properties of the different solid waste materials have to be carefully considered. For example, hard and brittle materials such as glass, ceramics and many construction wastes break easily under impact. Soft, elastic and fibrous materials, such as plastics, rubbers, metals, paper, textiles and wood, however, are best reduced by cutting or shearing action.

It is clear that any size reduction equipment to be used for nonsegregated solid wastes has to be capable of reducing both types of materials. In addition, the equipment has to be constructed to deal with solid wastes containing hazardous and nuisance materials which are occasionally found in wastes and could cause clogging, fires, and even explosions during the process. If these material properties are not taken into consideration, various difficulties could be experienced during the operation.

A survey of the equipment used for the disintegration of nonsegregated solid wastes indicates that no unit so far used disintegrates successfully all wastes. This is not surprising considering the complex nature of the system. In addition, most units used have been originally designed for other purposes. However, some have been slightly modified and a few incorporate in their design, two different sections for crushing and shredding. In most cases, however, it is found necessary to remove certain types of wastes to avoid major difficulties.

It appears from inquiries made to date that most of the units used today for the reduction of solid wastes consist of hammermills. The primary function of a hammermill is to fracture the materials by impact. Modifications introduced are usually specially designed hammers which aid in the disintegration of materials that are best disintegrated by a tearing or shredding action. However, this secondary function is usually only partially effective.

Difficulties have been encountered in size reduction operations utilizing hammermills. These are associated both with the properties of the materials to be reduced and with effects introduced by the operation itself. They include difficulties which are experienced with soft materials, such as coat hangers and textiles, which tend to wind themselves around the rotating parts and can cause stoppage of the equipment and can lead to breakage. Special hazards are also introduced by tramp metal and heavy metallic objects. Problems are also experienced during the operation due to the development of high temperatures and sparking which can cause fires.

However, it should be recognized that the material properties of reduced wastes are appreciably better than those of unprocessed wastes. The material is much more uniform, easier to handle and dispose of in landfills. The appearance is much improved and environmental pollution effects are reduced. Size reduction facilitates salvaging, incineration and composting operations. In cases in which size reduction leads to an appreciable decrease in volume of wastes, it also provides benefits with respect to the cost in transport.

ab) Size reduction costs

The operating and maintenance cost of present-day size reduction equipment can be appreciable. It depends primarily on the power consumption and metal wear of the equipment. These, in turn, depend on the design of the equipment and the material properties of the equipment components. The cost of size reduction operations are also affected by the nature of the feed material and the fineness of the resulting product.

A full survey of the costs of size reduction of wastes has not yet been completed. However, the operating costs for just electric power and maintenance of high capacity hammermills with wide screen openings are estimated according to manufacturers' information to approach $1.00 per ton for mills capable of processing several hundred cubic yards of wastes per hour. The capital cost of such large units is estimated to range from $300,000 to $500,000. It has been reported that about four people might be needed to operate the mill. Moreover, hammermill operations can be excessively noisy, generate huge amounts of dust and can create fires during the operation, particularly if inflammable materials such as lighter fluid cans, paints and varnishes are present. Environmental control equipment might therefore be needed and would add to the cost of the operation.

In addition, a demonstration of the shredding of solid wastes containing pieces of wood, several 55 gallon drums, a washing machine, and several tires, by a crusher-disintegrator was witnessed. The price of this machine, with a rated capacity of twenty tons per hour, was given at about $90,000. The largest machine of this type, with an output of 100 tons per hour, is priced at about $200,000. During the demonstration with the smaller model, about $10 worth of electricity was used per hour which equals 50 cents per ton. Operation of the machine caused a fair amount of dust. The maintenance cost, as estimated by the manufacturer, consists of daily lubrication and checking, and, at approximately 20 to 30 day intervals, a re-tipping of the hammers.

Furthermore, the cost of metal wear in refuse grinding can also be high. Damage and even breakage of metal parts is likely to occur if the machines are not designed to handle difficult materials. In addition to these scrap losses, the metal is worn away by abrasion and removed by dissolution in wet refuse grinding. It is found that metal losses due to abrasion and dissolution in wet and dry grinding differ appreciably. In wet grinding it is usually up to ten times higher than in dry grinding or crushing. In addition, the wear varies with machine and also in different parts of the same machine. The replacement costs for damaged metal parts, in particular the hammers and grates, might exceed 30 cents per ton. However, the cost for just the hammer wear appears to decrease by about forty percent if the grate opening is increased from about plus 2 to about plus 6 inches.

Overall, the cost of size reduction of solid wastes comparable in composition to those that can be handled by a large press can be estimated at upwards of 60 cents per ton. These costs can be estimated to break down roughly as follows: 35 percent for power, 40 percent for maintenance, and 25 percent for straight depreciation excluding interest and salvage.

b) Compaction of Solid Wastes

Compaction, like size reduction, is also discussed in terms of its technical implications and cost.

ba) Technical considerations

The simplest physical method for obtaining low volume, high density bundles of solid wastes is compaction of the materials in presses. During this process the materials are crushed and flattened and the air occupying the voids is expelled. The extent to which crushing and flattening takes place depends on the pressure exerted and the counter pressure developed by the compressed material. In the optimum case, all voids are eliminated and the resulting close contact between the materials facilitates adhesion and interlocking between the solids and the formation of a cohesive stable structure.

As discussed in the section on "Processing Objectives," the densities which could be achieved for highly compacted materials, can be close to those obtained for solid blocks of the same material. However, since the densities of different solids vary, individual bundles of the same volume will have different weights. Nevertheless, the density of well compacted bales is likely to be about twice that of the same material subjected to size reduction. This also means that compact bales could occupy only one-half or less of the volume required for shredded refuse.

As mentioned above, the achievable benefits, with respect to volume reduction and weight increase of solid wastes by compaction, appear to be appreciably higher than those which can be obtained by size reduction. It was felt, therefore, that the applicability of this process to solid wastes should be explored further.

To ascertain the feasibility of high pressure compaction to solid wastes, a series of preliminary experiments was conducted in small presses and metal balers. The information gathered by these spot tests and some of the conclusions drawn from them are given below:

i) In tests in which separate portions of the solid wastes were compressed in increments, poor compression resulted at the interface of each compressed portion. This effect persisted even when the final pressure was increased to 18,000 psi.

It was concluded, therefore, that a discontinuous feeding of materials requiring an intermediate compression should be avoided if at all possible.

ii) The magnitude of the applied pressure needed for suitable compaction of municipal solid wastes appear to be in the vicinity of 2500 pounds per square inch on the materials. In experiments carried out and limited to small size samples, an increase in applied pressure above 2500 psi did not produce an appreciable increase in the density (volume reduction) nor in the stability of the bale.

However, an addition of materials other than those contained in ordinary municipal waste, and changes in the size and configuration of the required bales might necessitate the utilization of presses with a higher pressure capacity.

iii) Solid wastes containing a high degree of moisture could not be compacted successfully by the existing compaction presses. Also, in those cases where refuse was compressed into bales or extruded, the sample disintegrated after the removal of the enclosure.

However, there were indications that a certain amount of moisture is beneficial in the compaction and/or extrusion of wastes containing large amounts of paper. Since a high moisture content appears to represent a major problem in the compaction of solid wastes, additional experiments are needed to determine the minimum and maximum amount which could be accommodated by the bales.

In addition, information should be gathered for determining the specific design parameters for presses which would allow the removal of excess moisture during baling. Alternative methods capable of reducing, advantageously, the material's moisture content, such as mixing of dry wastes with moist wastes and pre-drying, need further investigation.

Finally, there were also indications that slightly moist, extruded or pressed bales with a high paper content are more stable if dried subsequently than the bales made of fully dried materials.

iv) Best cohesion of the bales was obtained with samples which were made up of metal solid wastes found in municipal refuse. Improvement in the bale stability was also found in all cases in which the samples contained large portions of metal scrap.

The improved stability of bales in the presence of metal is attributed to the interlocking ability of the soft metals. This finding could be utilized in the final development of the baling method, should a greater stability of the bales be required. For example, metal screenings such as chicken wire rejects might be added to the wastes in an at-random fashion before compaction.

v) Spring-back, immediately after compaction, was experienced by bales containing primarily paper, and also in small compressed samples consisting of leaves and green twigs. In the latter samples, the twigs uncoiled and the sample disintegrated within a short period of time.

Spring-back is of importance for several reasons. It can affect the stability of the bale, it might affect the necessary compression speed as well as the system-associated material handling and space requirements.

vi) Glass was always crushed into small fragments during compression. Glass particles on the outside of the bale could present some hazard, since they appear to adhere poorly to the outer surface of the bale.

vii) The weights and volumes of the various compressed samples--per cubic foot--changed only slightly with applied pressure above 2500 psi. However, it should be borne in mind that only easily compressible materials were used in the above tests.

Large variations in weight were found, as anticipated, with samples of different compositions. This is not surprising since the weight of each sample per unit volume, if equally compacted, depends on the specific weights of the individual materials in it.

Bales of light weight materials, such as paper, therefore, will weigh less than bales made of heavy materials, e.g., metals and their alloys. The weights of the different compressed and extruded samples ranged from approximately 60 to about 170 pounds per cubic foot. Some of the samples appeared to contain a significant amount of absorbed moisture. However, the exact amount of the moisture and its contribution to the weight of the sample given could not be determined.

Thus, in order to produce bales of equal size and weight, a controlled mixing of the various inputs of solid wastes would be required. Unfortunately, such a process appears to be cumbersome, not very practical and really not justifiable. It is, therefore, more likely that ultimately either the size or the weight of the bale might have to be kept variable within certain, yet to be determined, limits by a partial mixing of the solid wastes. Such mixing, as indicated above, might anyhow be desirable to accommodate variations found in the moisture content of the incoming loads, e.g., restaurant refuse versus office paper refuse.

viii) Shredding of refuse before compaction, as compared to direct baling, did not appear either to aid the compaction process nor to contribute to the stability of the bale. Shredding of wastes appears to be necessary only if the size of the required bale should be relatively small.

The conclusions drawn from the above listed tests and additional information gathered from others who also conducted spot tests, show conclusively that high pressure compaction of solid wastes is feasible. However, they also show that more information is needed to develop a suitable processing method and equipment for the compaction of solid wastes.

bb) Compaction cost

The costs directly incurred in high pressure compaction tend to enhance the promise offered by this process for solid wastes in terms of technical performance. It should be recognized, of course, that the existing presses appear not to be suitable for the high pressure compaction of solid wastes because they were designed for different compaction purposes. Thus, the cost data presented in this section are only to indicate a very general order of magnitude and they are only to be used initially to guide future rail-haul development efforts.

Because of the varying densities of the input materials, it appears to be advantageous, at present, to use a more than one-stroke compression approach for the high pressure compaction of solid wastes. Among presses, the metal scrap balers or similar compaction devices appear currently to come closest to the requirements for a high pressure refuse compaction device. Consequently the following calculations are guided by the existing metal scrap baler owning and operating experience.

Metal scrap balers are usually three-stroke compaction devices which in the final compression stroke apply a force of 2000 to 3000 psi on the materials to be compressed. The operating speed of these machines may range on the average from 30 to 100 seconds per cycle and the useful service life is often quoted to far exceed 20 years. The hydraulic pumps, in a broad range, are frequently specified at 100 to 300 horsepower per machine with the full power being needed during less than 50 percent of the operations. The investment cost, finally, are quoted from $250,000 to $400,000 and the annual maintenance expenditures are estimated to run from two to three percent of the investment cost.

Within the framework of the above information it appears justifiable to establish the following basis for exploratory and developmental calculations:

i) Investment per compression device is $500,000.

ii) Useful service life is twenty (20) years.

iii) The straight depreciation costs amount to $25,000 per year; no salvage value is assumed.

iv) The power requirements amount to 500 horsepower and it is assumed that the full power will be required continuously.

v) Electricity is calculated at 1.5 cents per kilowatt/hour.

vi) The cycle time is 60 seconds.

vii) The processing throughput amounts to about one ton per minute or 260,000 tons per year.

Based on the above assumptions, which appear to be reasonable within the experience recorded above, the following cost per ton can be calculated:

Investment depreciation	$0.0962
Maintenance	0.0577
Electricity	0.0900
	$0.2439

Under the assumption of two percent maintenance expenditures and 200 horsepower pumps, the calculations would run as follows:

Investment depreciation	$0.0962
Maintenance	0 0385
Electricity	0 0370
	$0.1717

If one would assume a $300,000 investment and again two percent maintenance and 200 horsepower pumps the cost would drop as follows:

Investment depreciation	$0.0577
Maintenance	0.0231
Electricity	0 0370
	$0.1178

The above cost, like those quoted for size reduction, exclude any interest and return on investment expenditures. Nevertheless they suggest that the high pressure compaction of solid waste might turn out to be economically, a very attractive method of volume reduction.

4. Preliminary Processing Conclusions

To draw preliminary conclusions with respect to the processing of solid wastes for rail haul it appears advisable to establish some solid waste density benchmarks. Unfortunately the available data are quite spotty and this is no surprise considering the great variations found in the composition of the solid wastes.

The following data thus represent only very broad refuse density estimates and they give only a very tentative order of magnitude. The refuse densities most commonly quoted are as follows:

REFUSE DENSITY PATTERNS

Refuse Processing Method	Density Lbs./Cu.Yd.
Loose refuse, no processing	100 to 200
Refuse from a compactor truck after being dumped	350 to 400
Refuse compacted in a compactor truck	500 to 700
Shredded refuse	600 to 900
Refuse baled by a normal paper baler	800 to 1200
Refuse compressed in a metal scrap baler	1600 to 2200

It should be highlighted that depending upon the composition of an individual load, many exceptions to the above data may be found. However, the density relationship patterns suggest the obvious, that the high pressure compaction of solid wastes tends to produce the highest densities in the materials.

It can be stated that the presently available size reduction equipment appears to need considerable further technical development in order to be better usable for the disintegration of nonsegregated mixtures of solid wastes. Improvements in the technical design of units could eventually result in savings both with respect to operation and maintenance. At present, however, the processing and maintenance costs are quite high. Considering the great variety of the input materials, present-day size reduction appears to be too costly a process for homogenizing solid wastes.

Furthermore, it should be kept in mind also that size reduction even under optimum conditions, can lead only to a partial reduction in volume of solid wastes. In cases where compact materials are shredded, the ultimate volume occupied by the solid particles is actually appreciably higher than that of the compact item. If maximum reduction in volume is to be achieved, other methods have to be evaluated.

Unfortunately, the high pressure compaction of solid wastes is not without problems either, if one wants to obtain a stable bale. All the bales do not hold together as well as they should. However, in compaction the only sensitive or perhaps critical area appears to be the presence of excess moisture and not the presence of any of the solids normally found in a highly heterogeneous solid waste mixture. The cost for a high pressure compaction of solid waste might run at about 50 percent of those incurred in comparable size reduction methods.

Considering then both the promise and potential advantages of solid waste high pressure compaction, it appears very desirable to investigate the application potential of this process in more detail. This is done in a separate solid waste research project underwritten by the Solid Waste Program and the City of Chicago. This project was started recently and is described in the next section of this report.

Concluding the arguments about solid waste processing and to avoid misunderstandings, it must be emphasized, of course, that size reduction occupies a very legitimate and promising place in the broad field of solid waste disposal and its many varied aspects. There are instances in which the densities achievable through compaction are not required. There are other instances in which as heterogeneous a material mixture as contemplated for rail haul will not be handled; and there are obviously many instances in which compaction would even be detrimental to the disposal process objectives involved.

IV. SOLID WASTE HIGH PRESSURE COMPACTION TEST PROGRAM

The aim of the test program is to develop relevant information for the compaction of solid wastes, including the formation of stable bales, and to develop design criteria for presses and processing criteria for the baling of solid wastes.

The specific objectives of the program are:

...to determine the advantages and disadvantages of various bale sizes with respect to compression and/or baling,

...to determine the number and positioning of the strokes needed to produce suitable bales

...to investigate alternatives which would reduce the stroke requirements while enhancing the baling operation (e.g., the utilization of pressure or spring controlled counter-pressure plates), time and throughput are of considerable concern since rail haul deals with mass production type of operations,

...to explore the feasibility, parameters and operating requirements of extrusion,

...to measure the influence of variations in the pressures applied, in general, and within the framework of varying stroke arrangements,

...to analyze the impact of production cycle times and of the speed of compression,

...to investigate the production and handling parameters of varying bale configurations,

...to determine the workability of production-scale operations concerning bales of exact volume, exact weight, or exact density,

...to establish design criteria for the feeding devices needed,

...to evaluate the stability of bales of different sizes and configurations, especially with respect to rail transport conditions,

...to ascertain the influence and behavior of selected types of refuse and solid waste compositions under various pressures applied and within the framework of bale and press variations,

...to develop workable solutions for solving the moisture problem,

...to investigate the possibilities of achieving public health, and environmental control safeguards for the solid waste rail-haul system through compression and associated operations,

...to arrange for the necessary biological and chemical bale sample analyses,

...to specify the fail-safe provisions needed for full scale operations,

...to calculate the techo-economic parameters resulting from varying approaches to production-scale operations,

...to identify the instrumentation and controls needed for full scale operations, and

...to establish design criteria and performance specifications which can be released to various equipment manufacturers in order to foster competition and enlist their industrial development capabilities for the benefit of the rail-haul concept.

The importance of the accomplishment of the above objectives becomes clear if one considers their effect on the development of an effective solid wastes rail-haul system. Findings from the rail study show that the compaction of wastes is probably the most economical way to handle and transport wastes by a rail-haul system. Yet, in the absence of more specific data, this most vital systems input cannot be fully developed, and its impact on other system elements cannot be evaluated.

As mentioned before, high pressure compaction of solid wastes is technically feasible and so is the production of stable bales of solid wastes. However, the economics of the process and the properties of the compacted bales ultimately produced, affect significantly the utilization of material handling equipment, the types of railroad cars to be used, and the disposal methods. Furthermore, environmental factors have to be evaluated both with respect to the processing and the subsequent transport and landfill disposal.

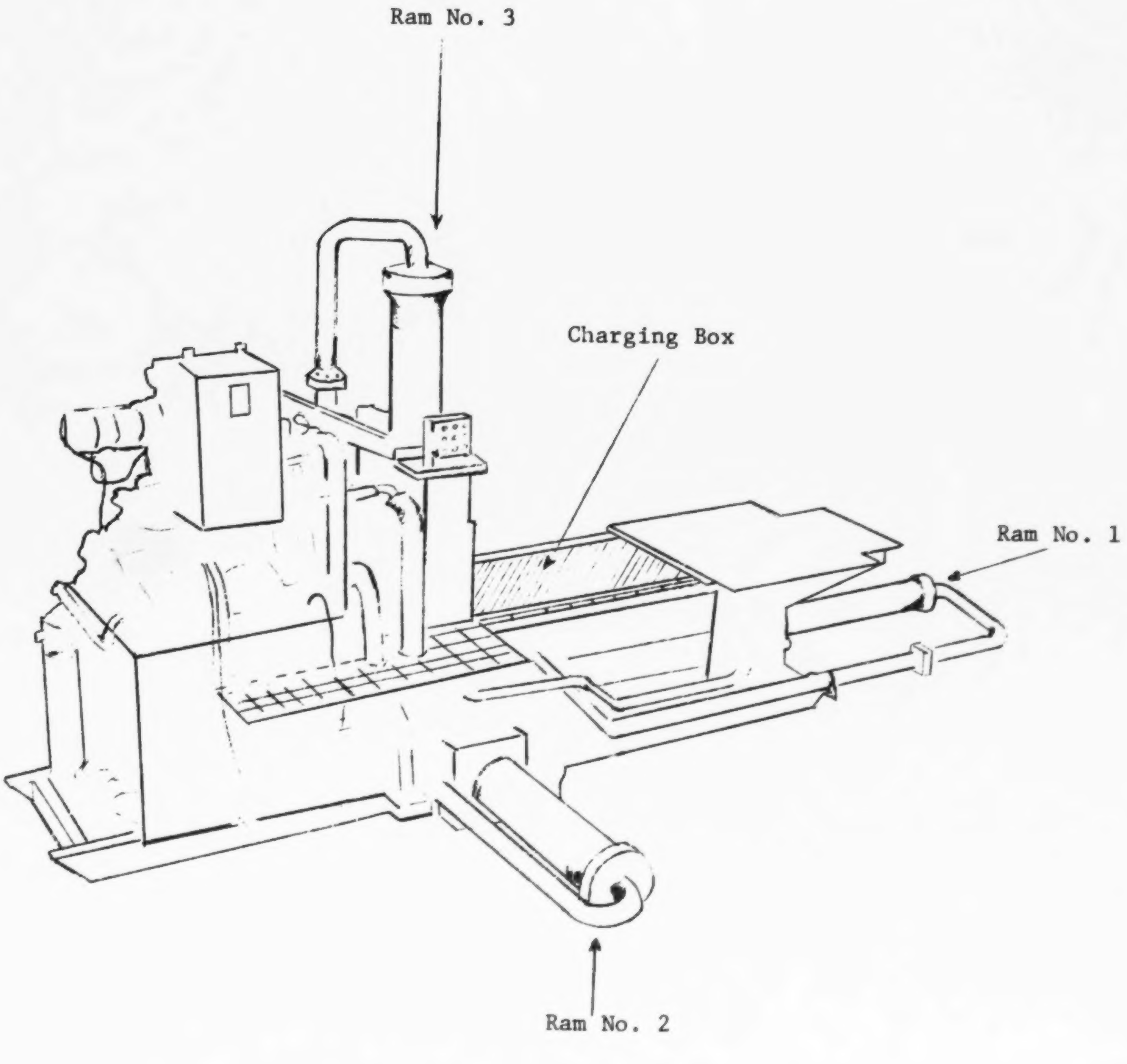
To achieve the above objectives and to carry out the experimental part of the test program, a useful scrap baler press, furnished by the Fisher Body Division of General Motors Corporation, has been obtained and been modified as far as possible. A sketch of a metal scrap baler similar to the one used in the test program is shown in Exhibit VI on the following page. The experimental part of the study is scheduled to start immediately after the project set-up phase is completed.

EXHIBIT VI

APWA SOLID WASTE
RAIL-HAUL PROJECT

ILLUSTRATION OF A

THREE-STROKE METAL SCRAP BALER


Ram No. 3
Charging Box
Ram No. 1
Ram No. 2

A brief description of the experimental approach to be used to obtain the required compaction and processing as well as some key press design and environmental control data, can be given as follows:

Compaction Testing, Processing and Press Design:

a) Initially, samples of predetermined composition will be prepared to determine the behavior of the various materials under compaction.

b) A series of samples, of the same composition, will be subjected to compression under different conditions. The effect of variables such as compaction pressure, compaction time, number of compaction strokes, bale size, moisture, etc., will be investigated.

   Similar experiments will be made using synthetic samples of different composition.

   Solid wastes to be used in the synthetic samples will be specially purchased, if necessary. Their physical and chemical characteristics will be identified, both before and after compaction.

   Volume and weight of the samples before and after different compaction experiments will be measured.

   The stability of the baled refuse will be tested experimentally.

c) Municipal, residential and selected industrial refuse will be subjected to compression under different conditions. As with the synthetic samples, compaction variables will be tested.

Oversized wastes, incinerator residue, garden and construction wastes will be tested on their own or in combination with other refuse.

d) The characteristics of the incoming refuse will be identified, and the behavior of the wastes under compression and after compression will be recorded.

Stability, volume reduction and densities will be determined.

e) The wastes will be treated, if it should be found necessary, to improve the adhesion and stability of the bales or to remove health hazards This would include tests of the effect of adhesives or coatings, heat, and other treatments.

f) The experimental results will be evaluated intermittently and after the completion of the work.

g) Criteria for new press designs adapted to the field of solid wastes will be developed on the basis of the findings of the project and other inputs.

h) The requirements necessary to obtain a suitable compaction process will be specified. This will also include composition, moisture, compaction pressure and other process variables.

Landfill, Health and Pollution Hazards:

a) Landfill cells to test the behavior of bales under environmental conditions will be constructed.

b) Processed wastes will be subject to a series of different conditions. Leachants from the wastes will be collected. Analyses of chemical and biological pollutants in various samples will be made. Both ionic species and gaseous decomposition products will be analyzed.

c) An attempt will be made to develop a suitable method for determining pathogens in the wastes. Samples from processed and unprocessed wastes will be analyzed for comparison.

d) Leachants released during compaction will also be collected and their pollution potential will be determined.

Special consideration is being given to the problems connected with the moisture and adhesive properties of the wastes. Both moisture and adhesive properties are important for the production of stable bales.

If the moisture content of wastes is too high, materials such as paper wastes, which absorb moisture readily, might acquire a pulplike consistency. This, in turn, would interfere with the compaction process since pulplike materials behave more like liquids than solids. In order to compact materials of this type it would be necessary to modify existing press equipment which is designed to compact solids alone.

It should be pointed out that a press designer would have to take into account that the water cannot be released easily from the pulp since it is bound strongly to the free hydroxyl groups of cellulose. The removal of water from cellulose by compaction is likely to be appreciably more difficult than the removal of the pulped portion of paper.

If it should be found that the moisture content of wastes is only occasionally above the limit acceptable in the direct compaction process, methods other than press modifications will be considered. Simple pre-mixing of different loads of refuse, some containing high and others low proportions of water, might be all that is required. However, if the average moisture content of wastes should be above the acceptable limit and if it cannot be removed during the compaction, more rigorous methods, such as drying, might have to be investigated.

There are three different mechanisms which could be utilized for the drying of wastes. These are: conduction, radiation and convection. In the first case, the heat is transferred indirectly through a wall, in the second and third case it is transferred directly to the solid either by electromagnetic radiation or by a gas heat-carrier. The use of any of these processes, if needed, would have to be explored in greater detail with respect to its applicability and its cost and performance. However, in order to do this effectively, it is first necessary to establish some of the limiting conditions which can only be obtained by determining the actual moisture content which can be accepted by the bale without causing major problems. Experiments of this type are scheduled for the test program.

As pointed out previously, the presence of a limited amount of moisture in wastes is most likely of appreciable benefit in the compaction of wastes. This assumption is based on the following considerations: paper, the main product of residential wastes, is made by a wet process which appears necessary to induce inter-fiber bonding. It is believed that the surface tension of water, if present in small quantities, forces the cellulose fibers into close contact.

The close contact between the fibers is further improved by applying pressure which leads to a flattening of the fibers and increases the possible area of inter-fiber contact. The surface tension of water, together with compaction, should facilitate bonding between papers appreciably. Therefore, it could be speculated that the most effective way of obtaining good adhesion in bales of solid wastes with a high paper content, without adding adhesives, would be in the presence of moisture.

The utilization of adhesives in the compaction of wastes could provide a very effective means to improve the stability of bales. The exploration of this avenue appears important since not only paper wastes but also other elastic wastes have a tendency to spring back after compaction. The tendency of unbroken fibers to unbend after the pressure is released could lead to a loosening of the bale. One could, of course, use strapping of bales as a means to improve their stability.

It should be stressed that the different technical approaches have to be evaluated not only with respect to their technical merit but also with respect to their cost performance implications.

V. MATERIAL HANDLING

Although it is always necessary and may be costly, material handling does not add visible value to a product. However, to be in a certain place at a certain time is, of course, of economic value.

The results of several surveys suggest that, on an industrywide average, material handling accounts conservatively for about 30 percent of the total cost of producing a finished product. Thus it is desirable to minimize the material handling functions through the layout of the process and to utilize the force of gravity in the handling of the materials whenever possible.

An analysis of the material handling requirements in a rail-haul transfer station must differentiate between the handling of the unprocessed and the handling of the processed solid wastes. Processed solid wastes will, naturally, represent more uniform material handling characteristics than the unprocessed materials, especially if a great variety of solid waste material is to be handled.

Material handling systems may comprise many individual mechanisms which need to be integrated into a network in order to be well balanced and effective. Basically the mechanisms provide a vertical or horizontal movement of the materials or a combination of both. This is accomplished by actions such as lifting, dragging, towing, pushing or carrying.

Material handling equipment can be designed to meet almost any performance requirements at a cost, of course. Some of the material movement characteristics of existing equipment can be gauged very broadly as follows:

SOME PERFORMANCE PARAMETERS OF SOME
SELECTED MATERIAL HANDLING EQUIPMENT*

Type of Equipment	Load (tons)	Speed (fpm)
Electric wire rope hoists	1-5	15-60
Industrial cranes	up to 15	10-35
Traveling cranes	up to 300	trolley 75-150
		bridge 100-300
Flight conveyor	several 100/hr	100
Apror conveyor	several 100/hr	100
Belt conveyor	several 1000/hr	700
Drag chain	10/hr	10-20

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*The equipment indicated is available with many different performance variations Not all of the available types and devices have been considered yet.

The above table is given to show that in terms of technical performance no insurmountable problems may be anticipated. However, to apply material handling principles to solid waste transfer stations, it is of key importance to determine (a) the rates of weight and volume by which the materials are to be moved and (b) the kind of movement required, i.e., continuous or periodic, e.g., for the feeding of the compaction press.

CHAPTER EIGHT - THE RAIL TRANSPORT FUNCTION IN A SOLID WASTE DISPOSAL SYSTEM

This chapter of the report focuses on the rail link between one or more transfer stations and the disposal site. The most striking result of this segment of the study is the great variety of alternatives provided in the use of rail as the key transport mode for a solid waste disposal system.

I. THE POSITION OF RAILWAYS IN FREIGHT TRANSPORT IN THE UNITED STATES

As shown in Exhibit VII on the following page, railroads represent the leading mode of transportation for the movement of freight. Motor trucks take second place, pipelines third and barges fourth. Freight, in this statistic, includes solid as well as liquid materials which explains the relatively high share of the pipeline transport.

The rail data presented throughout this rail-haul study are derived from the operating experience of Class I line-haul railways. These include the carriers having annual revenues of $5 million or more. Class I line-haul operating companies

... represent only about 12 percent of the companies connected directly with the execution of rail transport,

... operate, however about 96 percent of the total miles of main track, including trackage rights,

... own about 93 percent of all the locomotives and about 98 percent of all the freight train cars in service,

... employ about 93 percent of all railroad personnel,

... carry about 95 percent of the total freight tonnages,

... account for about 99 percent of the freight revenue ton-miles,

... earn about 96 percent of the total railway operating revenue, and

... represent about 95 percent of the total capital stock of the industry.

Thus, Class I railroad transportation data can be used to develop realistic solid waste rail-haul configurations.

EXHIBIT VII

FREIGHT TRAFFIC IN THE UNITED STATES BY RAILWAYS, MOTOR TRUCKS, GREAT LAKES, INLAND WATERWAYS, AND PIPELINES, CALENDAR YEARS

1961, 1962, 1963, 1964, and 1965, AND PERCENTAGES OF TOTAL

NET TONS IN MILLIONS

		RAILWAYS		MOTOR TRUCKS[1]		GREAT LAKES		INLAND WATERWAYS		PIPELINES	
Year	Total	Net Tons	% of Total	Net Tons	% of Total	Net Tons	% of Total	Net Tons	% of Total	Net Tons	% of Total
1961	2,720	1,194	43.9	289	10.6	137	5.0	388	14.3	712	26.2
1962	2,858	1,234	43.2	321	11.2	136	4.8	418	14.6	749	26.2
1963	2,962	1,285	43.4	338	11.4	142	4.8	431	14.5	766	25.9
1964	3,131	1,356	43.3	366	11.7	151	4.8	457	14.6	801	25.6
1965	2,853	1,388	48.7	- [2]	-	154	5.4	472	16.5	839	29.4

TON-MILES IN BILLIONS

		RAILWAYS		MOTOR TRUCKS[1]		GREAT LAKES		INLAND WATERWAYS		PIPELINES	
Year	Total	Ton Miles	% of Total	Ton Miles	% of Total	Ton Miles	% of Total	Ton Miles	% of Total	Ton Miles	% of Total
1961	1,318	570	43.2	305	23.2	87	6.6	123	9.3	233	17.7
1962	1,392	600	43.1	331	23.8	90	6.4	133	9.6	238	17.1
1963	1,461	629	43.1	348	23.8	95	6.5	139	9.5	250	17.1
1964	1,535	666	43.4	350	22.8	106	6.9	144	9.4	269	17.5
1965	1,666	709	42.6	388	23.3	110	6.6	153	9.2	306	18.3

Source: Annual Reports of the Interstate Commerce Commission

[1] Tons of revenue freight carried in intercity service by Class I carriers.

[2] The figures for motor trucks were not available for 1965.

Excluding Alaska and Hawaii, these railroads serve each State of the Union and rails are, of course, available in all provinces of Canada. The rail network is especially long in Texas and Illinois as well as in California, Iowa, Kansas, Minnesota, Ohio and Pennsylvania.

However, the length of the rail network must be related to the total area and/or the population in order to provide some rail service perspective. The lower the number of square miles per mile of road the better the potential to serve a given area. The higher the population density per mile of road, the greater the potential benefit to a maximum number of people.

Exhibit VIII on the following page shows the rail network mileage of the United States broken down by states. It also gives the ratios of square miles and the number of people per mile of railroad.

II. SOLID WASTE RAILROAD CARS

The rail haul of solid wastes might be implemented by using either existing or specially designed freight cars. The ultimate decision as to which type of car to use depends, of course, upon the form in which the solid wastes are to be shipped, e.g., unprocessed, compacted, in stable or in unstable bales. Finally, there exists a manifold interdependence between the type of car, the physical form of the solid waste shipment and the material handling requirements associated directly with the loading and unloading of the car.

THE RAILROAD NETWORK IN THE UNITED STATES
BROKEN DOWN BY STATE AND RELATED TO
STATE AREA AND POPULATION

EXHIBIT VIII
APWA SOLID WASTE
RAIL-HAUL PROJECT

State	Total Miles of Railroad	Number of Square Miles per Mile of Road	Number of People per Mile of Road (1960 Population)
United States Total	212,059	16.74	932
Alabama	4,624	11.16	707
Arizona	2,053	55.51	634
Arkansas	3,725	14.26	480
California	7,516	21.11	2,091
Colorado	3,775	27.62	465
Connecticut	773	6.48	3,279
Delaware	293	7.02	1,522
Florida	4,578	12.79	608
Georgia	5,567	10.58	708
Idaho	2,677	31.21	249
Illinois	10,996	5.13	917
Indiana	6,525	5.56	715
Iowa	8,437	6.67	327
Kansas	8,059	10.21	270
Kentucky	3,525	11.46	862
Louisiana	3,899	12.44	835
Maine	1,691	19.64	573
Maryland	1,135	9.32	2,732
Massachusetts	1,573	5.14	3,274
Michigan	6,461	9.01	1,211
Minnesota	8,037	10.46	425
Mississippi	3,632	13.14	600
Missouri	6,513	10.70	663
Montana	4,939	29.79	137
Nebraska	5,574	13.85	253
Nevada	1,635	67.61	174
New Hampshire	817	11.39	743
New Jersey	1,853	4.44	3,274
New Mexico	2,190	55.56	434
New York	5,858	8.46	2,865
North Carolina	4,270	12.34	1,067
North Dakota	5,195	13.60	122
Ohio	8,139	5.06	1,193
Oklahoma	5,604	12.48	415
Oregon	3,161	30.68	560
Pennsylvania	8,693	5.18	1,302
Rhode Island	157	7.73	5,471
South Carolina	3,261	9.52	731
South Dakota	3,910	19.71	174
Tennessee	3,339	12.65	1,068
Texas	14,277	18.73	671
Utah	1,725	49.23	517
Vermont	719	13.36	542
Virginia	4,085	9.99	971
Washington	4,955	13.76	576
West Virginia	3,582	6.75	519
Wisconsin	6,133	9.16	644
Wyoming	1,848	52.98	179
District of Columbia	31	2.23	24,645

Source: Data developed from information published by the Interstate Commerce Commission and U. S. Bureau of the Census

Population 197,566,000
U.S. Land Area 3,549,000 Miles

1. Existing Freight Train Cars

A great variety of freight train cars are used by the railroads to accommodate the needs of the various shippers. However, due to the great variety of individual shipping conditions and to maximize, nevertheless, the utilization of the available equipment, it is not surprising that general purpose cars are prevalent. Thus, from an investment point of view and considering the great importance of equipment utilization, it appears advisable to keep multipurpose functions in mind in designing special railroad cars.

At present, there are about 1,534,000 freight train cars in service. About 1,504,000 of these cars are owned by the Class I railroads. A breakdown of these freight train cars by class is presented as follows:

THE COMPOSITION OF THE FREIGHT TRAIN CAR POOL
OWNED BY CLASS I RAILROADS

Class of Cars	Number Owned by Class I Railroads	Percent Share of Total
Boxcars, general service	515,123	34.1
Boxcars, special service	81,220	5.3
Flatcars	48,257	3.3
Stock cars	22,445	1.5
Gondola cars	222,897	15.1
Hopper cars, open top	431,791	28.7
Hopper cars, covered	81,168	5.3
Refrigerator cars	36,922	2.4
Rack cars	41,075	2.7
Tank cars	5,157	0.4
Other freight train cars	2,330	0.2
Caboose cars	15,549	1.0
TOTAL freight cars	1,503,934	100.0

Source: Interstate Commerce Commission, 1967
Transport Statistics in the United States, Year ended December 31, 1964

The above data indicate that general service boxcars, open hopper cars, and gondolas represent more than three-fourths of the freight cars in use. No other type makes up as much as six percent of the total.

Since solid wastes can be processed and/or handled in a way to suit many different types of cars, it is necessary to investigate the influence of the railcar acquisition cost. The order of magnitude for the average cost of new freight train cars in 1967 was as follows:

AVERAGE PURCHASE PRICE OF FREIGHT TRAIN CARS

Class of Cars	Average Cost per Unit
Boxcars, general service	$ 14,000
Boxcars, special service	18,500
Flatcars	16,000
Stock cars	12,000
Gondola cars	13,000
Hopper cars, open top	12,000
Hopper cars, covered	16,000
Refrigerator cars	23,000
Rack cars	12,500
Tank cars	20,000
Caboose cars	18,000

Source: Manufacturer data, Interstate Commerce Commission

The above price variations must be analyzed further in the context of car service life, car utilization, interest, return on investment and, of course, depreciation. Based upon Internal Revenue Service regulations the service life of rail cars is commonly estimated to range between 10 and 15 years.

Thus, using a ten year depreciation period the annual charges would range from $1,200 to $2,300 per car. Based on 250 trips per year with loads averaging 50 tons per car, these charges would amount to from $0.09 to $0.18 per ton. To gauge the dimensions of the total car investment, it appears necessary to increase the above cost per ton by perhaps 100 percent or more in order to make allowances for interest and return on investment.

Nevertheless, in view of these relatively low investment costs, it does appear that the car investment cost alone should not be taken as the decisive factor in the selection of equipment. Therefore, it is suggested that the choice of a particular type of car should be based primarily on its operational advantages and flexibility.

The above calculations, however, indicate that car utilization (i.e., the number of trips and net load) will, in conjunction with the investment costs, influence the feasibility of solid waste rail haul to perhaps a considerable degree. A decrease in either the number of trips or the net load or both will increase the investment cost per ton.

The length of haul, travel speed and turn-around time will determine, for example, whether a given trip can be made every day or not. If a car can be used productively only every other day then twice as much equipment would be needed to haul the given tonnage of waste daily to the disposal site. As a result, the car investment cost per ton would double regardless of what type of car is employed.

It should be mentioned in this context that according to data from the American Association of Railroads a freight car makes on the average only about 15 trips per year. Thus solid waste rail haul appears to be a proposition which offers exceedingly good operating conditions.

2. The Applicability of Existing Freight Train Cars for the Transport of Solid Wastes

The form and function of each type of freight train car is inherently related to the types of cargo it is designed to carry. The more specialized, less prevalent type of freight cars makes the relationship between form and function quite obvious. One would not use boxcars, hopper cars or gondolas to ship bulk liquids, cattle, or finished automobiles but would employ instead tank cars, stock cars, and rack cars.

If the solid wastes, thus, are to be transported in existing freight train cars, then they must be processed in such a way as to suit the conditions of the cars given. The form and function of existing freight train cars and the respective implications for the transport of solid wastes can be presented briefly as follows:

a) Boxcars

According to its name the boxcar is enclosed on all sides and has a roof. One or more doors are placed on each of the long sides of the car.

The boxcar is used especially for shipments which must be protected from the weather. As a rule, the shipments consist of boxed, crated, or bagged materials or products which can be readily handled in unit loads as, for example, on pallets moved by a fork lift truck.

Concerning the transport of solid wastes, boxcars would provide protection from the undesirable effects of rain or snow. However, they are unsuited to the transport of loose or shredded solid wastes due to the loading and unloading difficulties introduced. On the other hand they are suitable for compacted wastes which can be loaded and

and unloaded in the same manner as bagged or boxed materials.

b) Flatcars

Flatcars consist of just the car floor without any housing or body above. Some of the flatcars have bulkheads or even moveable bulkheads to adjust to varying material transport requirements.

Flatcars are used for piggy-backing and container service as well as the transport of pulpwood, plywood, plaster board, pipe or poles or similarly long items, steel products and machinery. The utilization of flatcars is on the increase because of the ease and flexibility of the loading and unloading.

Flatcars, of course, would be wholly unsuited for the transport of loose or shredded refuse unless such wastes were first placed in containers. However, they might offer advantages for the shipment of baled refuse depending on the stability, condition and appearance of the bales. Specifically, flatcars with moveable bulkheads, might meet the requirements for the transport of baled solid wastes, if covers are not required.

c) Gondola cars

Gondola cars come equipped with sides and ends but without a top cover. The car floor is approximately level and may be provided with bottom doors and/or drop ends. The sides of the car may be high or low. Several types of removable covers are available. They protect the shipment from the weather but do not interfere with the loading or unloading operations.

Gondolas are used for all kinds of shipments including minerals, steel products, machinery, container, lumber, wood products and wastes. Gondolas, in particular, are suitable for commodities which are bulky or not uniform in size, as for example, blocks of granite. High cube, bottom dump gondolas, ($32,000) are frequently utilized in the transport of wood chips and sawdust and they are almost identical to open hopper cars.

Assuming that a cover is provided and that the refuse has a sufficiently low moisture content, gondolas could be used satisfactorily to transport unprocessed, as well as processed - particularly baled-solid wastes. The loading and unloading process would, of course, vary with the condition in which the materials are shipped. However, several types of suitable equipment are available including car dumpers ($200,000 to $500,000 -- excluding the foundation and pit) and cranes.

d) Hopper cars

Hopper cars are designed to discharge their loads by gravity through hopper doors. Thus they have floor sections and/or sides sloping to the one or more hoppers per car. A covered hopper car has a permanent roof equipped with hatches.

Hopper cars are used for the transport of relatively free flowing materials of a given size including high as well as low density commodities. Coal, stone, ballast, ore, coke, cements, sawdust and wood chips represent prime examples. Large, standard size hopper gates measure approximately 25 by 48 inches.

Open-top hopper cars could be readily loaded with unprocessed solid wastes. But serious difficulties would occur in the unloading of the car due to both the matting and clinging properties of the materials and the presence of oversized items. These problems could probably be alleviated somewhat if the wastes were shredded.

However, these problems might be averted altogether if the refuse were compacted into briquettes of the size of baseballs or footballs. In such forms, the adverse material properties, as indicated by the steep angle of repose, might have been overcome to such a degree that the free flow of the individual blocks would not be impaired.

The existing covered hopper cars do not appear to be suitable for the hauling of solid wastes since they are designed primarily for the shipment of powdered or granular materials.

e) Tank cars

The existing tank cars have only relatively small loading and unloading openings. Thus they could be used only if the wastes were ground to a sufficiently small size to pass the entry and exit ports. However, the unloading of the solid wastes, whether by air or liquid pressures might pose considerable problems due to settling, clogging, and the varying densities of the solid waste materials.

f) Refrigerator cars

Refrigerator cars are similar to boxcars with the additional feature of temperature control and heavy insulation. For solid waste shipments refrigerator cars could be used with advantage since low temperatures, 40° to 45° F. inhibit bacterial activity and the decomposition of the wastes. However, cooling involves a cost to be weighed against the value of the possible benefit.

A review of the preceding illustrative and not exhaustive discussion suggests that the choice of rail car for the transport of solid wastes is no simple matter. The loading and unloading methods which have to be used for the different cars represent only the most immediate effects. Other effects caused by the choice of car are felt on system variables from beginning to end. The type of car selected influences, for example, both the transfer station as well as the disposal operations in their respective material handling and/or processing requirements.

The foregoing discussion suggests that compaction of the materials into relatively stable bales appears to be needed if maximum flexibility in the utilization of the different existing freight cars is to be achieved for solid waste rail haul.

3. Car Utilization in Terms of Volume/Net Load Relationships

With respect to the transport of solid wastes by existing freight train cars, the relationship of volume and net load carrying capability is important.

The theoretical limits of the volume/net load relationship are given in Exhibit IX on the following pages. The data refer to the most common types of freight train cars. However, to add perspective, information on Hi-Cube cars is also included although the number of such cars in service appears to be rather small.

In evaluating the theoretical limits, it must be recognized that they tend to exceed the nominal carrying capacity given for the cars. Since it is desirable for both the shipper and the carrier to utilize the maximum load carrying capacity as much as possible, there is a movement under way to reclassify the freight cars in terms of their maximum load limits.

EXHIBIT IX
APWA SOLID WASTE
RAIL-HAUL PROJECT

THEORETICAL LIMITS OF THE VOLUME/NET LOAD RELATIONSHIP IN EXISTING FREIGHT TRAIN CARS

TYPE OF CAR (NOMINAL CAPACITY)	SPECIAL FEATURES	CAPACITY (Cu. Ft.)	MAXIMUM LOAD LIMIT (Lbs.)	LBS./ Cu. Ft.
Gondola Cars				
50 ton	low sides	1,153	129,000	112
50 ton	all steel, drop bottom	1,948	100,000	51
50 ton	fixed-end, drop doors	1,948	100,000	51
70 ton	fixed-end	1,700	151,000	89
70 ton	fixed-end	1,995	158,200	79
70 ton	fixed-end	1,995	162,600	82
70 ton	mill type, drop ends	1,776	144,800	82
70 ton	mill type, drop ends	1,775	141,400	80
70 ton	wood floor, ends, & sides (for sulfur load, only)	1,573	158,700	101
70 ton	drop bottom for handling coke	3,125	153,600	49
70 ton	fixed-end, 16' drop doors	2,410	140,000	58
70 ton	solid bottom, movable bulkheads	2,868	143,000	50
70 ton	covered, steel floor	3,520	146,500	42
70 ton	covered, bulkheads	2,324	140,000	60
70 ton	high plywood side, drop bottom for wood chips	6,014	136,500	23
100 ton	non-railroad owned	4,300	250,800	58
Hopper Cars				
50 ton	open top, double hopper	2,160	135,200	63
70 ton	open top, triple hopper	2,460	168,200	68
70 ton	open top, triple hopper	3,030	164,100	54
70 ton	open top, triple hopper	2,700	157,000	58
80 ton	open top, triple hopper	2,960	166,100	56
80 ton	open top, triple hopper	2,821	166,300	59
90 ton	open top, triple hopper	2,868	202,600	71
90 ton	open top, double hopper	2,100	191,900	91
95 ton	open top, triple hopper	3,418	204,300	60
100 ton	automatic dumping, open top	3,600	200,000	56
100 ton	open top, triple hopper	3,418	201,300	59
100 ton	open top, triple hopper	3,366	200,000	59

EXHIBIT IX (continued)

TYPE OF CAR (NOMINAL CAPACITY)	SPECIAL FEATURES	CAPACITY (Cu. Ft.)	MAXIMUM LOAD LIMIT (Lbs.)	LBS./ Cu. Ft.
Hopper Cars (continued)				
100 ton	open top, quadruple	3,483	200,000	57
100 ton	open top, sextuple hopper	4,003	195,200	49
100 ton	wood chip car, sextuple hopper	7,000	200,000	29
90 ton	wood chip car, sextuple hopper	7,000	188,500	27
70 ton	wood chip car	5,850	143,500	25
Boxcars				
50 ton	15 foot door	4,888	92,900	19
50 ton	8 foot door	3,908	100,000	26
70 ton	16 foot double doors	4,932	152,600	31
70 ton	16 foot double doors	4,884	156,400	32
70 ton	16 foot double doors	4,952	155,300	31
80 ton	16 foot double doors	6,013	176,000	29
90 ton	single door	6,146	180,000	29
100 ton	16 foot double door	5,980	181,400	30
70 ton	hi-cube for low density packaged goods	10,000	105,500	11
70 ton	hi-cube two 16 foot double doors	10,000	102,100	10
70 ton	hi-cube for low density auto parts	10,000	110,400	11

Flat Cars	APPROXIMATE AREA (Sq. Ft.)	LOAD LIMIT (Lbs.)
50 tons	53 x 10 = 530	114,800
50 ton	45 x 10 = 450	111,300
70 ton	56 x 9 = 504	152,700
70 ton	60 x 9 = 540	148,800
70 ton	60 x 10 = 600	150,500
70 ton	53 x 10 = 530	170,400
80 ton	60 x 10 = 600	183,500
90 ton	58 x 9 = 522	184,400

Source: Manufacturers and Railroad Data, Car and Locomotive Cyclopedia, 1966, (Simmons-Boardman Publication).

It must be highlighted, of course, that the theoretical load density limits do not take into account the practical loading patterns that might be achieved. It is safe to say that the practical loading patterns might reduce the available car volume capacity at least by about 15 to 20 percent. This, in turn, would increase the individual pounds per cubic foot values given by about 20 to 25 percent. Furthermore, due to loading constraints, the practically available space on boxcars might be considerably less than indicated.

Thus, the information in Exhibit IX can be taken to suggest that a cargo density of one ton per cubic yard or about 80 pounds per cubic foot would be optimal with respect to the utilization of most of the existing freight train cars. Correspondingly, if special cars are to be designed, if these special cars are to serve multipurpose functions as much as possible, and if the multipurpose functions needed are represented in the profiles and number of the existing railcars, then even the specially designed cars might have to be focussed in their volume/weight relationship on the density given above.

In evaluating this finding, it must be recognized that the center of gravity should be no higher than 96 inches from the top rail. The closer a car's center of gravity gets to the 96 inches the more likely it is to tip over. A car may tip over when it rounds a banked curve where the outer rail may be as much as six inches higher than the inside rail. Also, a car may tip over as a result of its rolling from side to side during the trip. The position of the center of gravity, the conditions of the road bed and the route, influence, of course, the train speeds permissable and therewith the turnaround time for the equipment.

The economic characteristics of hauling materials at various densities by rail tend to support the contention that solid wastes be highly compacted for shipment. A comparison between the utilization of Hi-Cube covered hopper cars with a usable capacity of 7,000 cubic feet for the shipment of loose solid wastes and the use of gondola cars for the shipment of baled wastes is given as follows:

COMPARISON OF THE ECONOMIC CHARACTERISTICS OF RAIL HAUL AS AFFECTED BY VARIATIONS IN THE COMMODITY DENSITIES AND BASED ON A 100 MILE HAUL IN UNIT TRAIN OPERATIONS
(in dollars per ton)*

Total Payload of Train (tons)	Hi-Cube Car Density Lbs/cuft 10 (dollars)	Hi-Cube Car Density Lbs/cuft 25 (dollars)	Gondola Car Density Lbs/cuft 30 (dollars)	Gondola Car Density Lbs/cuft 80 (dollars)
600	$5.60	$3.65	$4.00	$2.20
1200	4.25	2.55	3.35	1.65
1800	3.75	2.10	3.15	1.45

Source: Pricing Research, Penn Central Railroad, 1968

* The data represent rough though reliable approximations

At 25 pounds per cubic foot the weight of a cubic yard of solid waste would amount to 675 pounds. This is a value which might be assumed for just this calculation to represent a maximum density for unprocessed solid waste. It is known, of course, and as shown in Chapter Seven, that the density of unprocessed solid wastes are significantly lower and that the value indicated falls into the lower range for shredded materials. At 80 pounds per cubic foot the weight of a cubic yard of solid waste would exceed one ton.

The data suggest that the cost differential in the shipment of unprocessed wastes and that of highly compacted solid waste decreases with an increase in the total payload of the train. Under high volume levels and a relatively high density of the unprocessed materials the difference might be as little as $0.65 per ton. Under low volume levels and an average material density of the unprocessed wastes the difference may amount to as much as $3.40 per ton. Thus, considering merely the transport function and considering only unfavorable conditions, the compaction process should not cost more than $0.65 per ton.

Finally, it should be mentioned that some consideration is also given to the development of specially designed solid waste rail-haul cars. However, the use of special purpose cars requires a considerable initial investment due to the large solid waste shipping volumes involved and/or the minimum volumes required for rate economics. It appears to be impossible to demonstrate the total, i.e., the technical and economic feasibility of rail haul in small scale demonstration projects.

III. TRAIN CONFIGURATION

The train configuration can be discussed in terms of train-type alternatives and locomotive power.

1. Train-Type Alternatives

There appear to be four basic train-type alternatives which are potentially applicable to a solid waste rail-haul system. Choice of any one would depend on the specific set of circumstances which exist in the local or regional network, e.g., the waste volume, the number of originating points, desired schedules and turn-around requirements.

a) Regular freight train service

In the regular service configuration one or more carloads of solid waste would be handled like the carloads of any other commodity. They would simply be attached to a regularly scheduled freight train.

This approach offers considerable flexibility in operations but poses one restriction on the railroad. This restriction requires that the refuse car is not subject to excessive delays in transit. The car must move promptly with a yet to be determined time span all the way to its destination.

However, this alternative does not necessarily serve all communities since some have only infrequent freight service. In addition, the selection of suitable disposal sites would be restricted to points on route where the respective freight trains can drop off the solid waste car or cars.

Finally, it should be recognized that the refuse cars used in such service might have to be dedicated exclusively to the transport of solid wastes and might not be available for any other shipment. This requirement, however, is entirely compatible with normal rail operations and does not impose something new into railroad practice. A 100 percent empty return of the thus specially dedicated car or cars, might, of course, increase the solid waste transportation cost.

b) Dedicated freight train service

The second alternative is to make up and use a special train dedicated in its entirety to the rail haul of solid wastes. This does away with the need to conform to regular freight schedules.

Dedicated service gives the disposal system a free hand in fashioning its own schedule more fully in line with the local conditions in the waste originating communities. This alternative could accommodate even those communities which have infrequently scheduled regular freight service. It also allows more flexibility with respect to the location of the disposal site.

The special service train does resemble a unit train except that the typical unit train travels between only two points without stops enroute and often pulls 100 cars or more. A special solid waste train, however, can run economically even with fewer cars and with stops along the route. Thus, to gain a maximum advantage, the unit train concept must be adapted to fit solid waste rail-haul requirements and should not be adhered to slavishly.

c) Return haul by unit train

It is entirely conceivable to use the empty return haul of an existing unit train and thereby gain some economies by using solid wastes as a return payload. This alternative, unfortunately, is not universally applicable. There are relatively few points, and their operators (the present shippers) cannot allow disruptive changes in the schedule or in the overall train speed.

Nevertheless, this alternative could find an application for processed wastes on a selective geographic basis and should be therefore given careful consideration. Two arguments can be cited in support of this approach.

First, the cars in unit trains are ordinarily hoppers which, as indicated previously, are either bottom or side dumpers. These cars are already available and can accommodate solid wastes in the form and size of briquettes or small blocks to facilitate loading and dumping. Second, the origination point of unit trains is usually a coal mine which offers great promise for refuse disposal while the destination point is usually in or near an urban center where the great quantities of solid wastes originate.

d) Rent-A-Train

The Rent-A-Train concept was recently introduced by the Illinois Central Railroad and pertains primarily to the financial aspects of solid waste haul by rail. The IC plan applies only to the shipment of specific agricultural commodities from originating points in the midwest to specific Gulf Coast ports. The present plan involves hauls of at least 600 miles one-way.

As constituted today, the plan offers a shipper eighty-six 100 ton cars in one cut plus motive power on short notice whenever requested. The cost consists of an annual charge of $1 million plus 1.5 mills per trailing ton-mile for a 600 mile one-way haul. Interest in the concept arises from the significant reduction in freight cost when a user can arrange for an intensive utilization of the train. This is, of course, the case in the shipment of solid wastes by rail where large tonnages might have to be transported daily.

2. Locomotive Power

Locomotive power must be selected with respect to the total weight of the train to be pulled and the track conditions. A locomotive must be strong enough to do the hauling but not excessively large and costly. The order of magnitude in locomotive pulling power and unit cost is as follows:

Class of Locomotive	Average Weight per unit (tons)	Average tractive effort/ unit (lbs.)	Average cost	Average Cost per lb. of tractive effort
Diesel-Freight "A" Units				
Type B-B, 1,800 Hp.	132	65,700	$195,000	$ 2.97
Type B-B, 2,250 Hp.	131	65,500	225,000	3.44
Type B-B, 2,400 Hp.	121	64,300	220,000	3.42
Type B-B, 2,500 Hp.	131	64,200	223,000	3.47
Type B-B-B-B, 5,000 Hp.	280	139,800	490,000	3.51
Type B-B-B-B, 5,500 Hp.	276	137,800	595,000	4.32
Type C-C, 2,450 Hp.	184	91,900	215,000	2.34
Type C-C, 2,500 Hp.	146	77,000	235,000	3.05
Type C-C, 2,700 Hp.	191	97,000	275,000	2.84
Diesel-Multipurpose "A" Units				
Type B-B, 2,000 Hp.	133	57,600	212,000	3.68
Type B-B, 2,250 Hp.	124	61,700	215,000	3.48
Type B-B, 2,400 Hp.	132	65,800	230,000	3.50
Type B-B, 2,500 Hp.	126	65,000	225,000	3.46
Type B-B, 5,000 Hp.	243	139,200	500,000	3.59
Type C-C, 2,500 Hp.	178	43,000	270,000	2.90
Type C-C, 2,750 Hp.	188	88,700	290,000	3.27
Type C-C, 4,000 Hp.	154	118,000	540,000	4.58
Type C-C, 4,300 Hp.	177	132,000	525,000	3.97
Type D-D, 5,000 Hp.	242	131,700	440,000	3.34

Source: Data from Interstate Commerce Commerce Commission Publications and Manufacturer Information

The data presented in the above tabulation, indicate that the investment cost for the tractive effort amount to about $3.50 per pound. The tractive effort includes the force needed to move the locomotive as well as the drawbar pull. The drawbar pull is the amount of force a locomotive can exert on its rear coupling to move the train of cars attached to it.

As a rule, 20 pounds of drawbar pull per ton of total train weight are needed to start a train. The train weight includes the net load on the cars as well as their dead weight or tare weight. Thus, 60,000 pounds of drawbar pull are considered capable of moving 3000 tons of train. The less the dead weight per car the more payload can, of course, be accommodated.

Adverse grades, in particular, are a significant factor in the selection of a locomotive. Each percent of adverse grade requires that, at least, an additional 20 pounds of drawbar pull per ton of train must be available. Consequently, at a one percent adverse grade, a locomotive with 60,000 pounds drawbar pull can only be used with a 1500 ton train since the unit must be capable of starting by its own power should it have stopped on the adverse grade. It is obvious that in this configuration the cost per ton of material moved will increase significantly.

Furthermore, the curves encountered along the route require another 0.8 pounds per ton of train weight for each degree of curve to compensate for the increased friction and drag between the wheel flanges and the rails. In like manner, provision must be made for wind resistance against the cars as a consequence of their motion, i.e., this provision varies with the train speed and whether each car has 4-wheel or 6-wheel trucks. All these things and more need be ascertained merely in order to select an adequate locomotive and to begin the calculations of its fuel consumption, travel speed and associated costs.

The implications of train configuration for the service pattern of solid waste rail haul can be readily ascertained. Underutilization of the locomotive power might allow that additional, perhaps smaller, communities be picked up at perhaps only an incremental cost. Full utilization of the locomotive, on the other hand, might eliminate the possibility of providing solid waste rail-haul service to some communities since the addition of another power unit for insufficient freight might cause an unjustifiable increase in the total as well as the properly distributed cost. Even a relatively small increment in the cost adds up to considerable total expenditures if one considers the total number of tons shipped during the course of a year.

IV. THE COST OF LAYING TRACK

To gain access to desirable disposal sites it may be necessary to build new tracks in certain instances. These tracks should be capable of carrying heavy loads and, perhaps, of accommodating heavy traffic. One may gain some appreciation of the cost of laying track by considering data reported to the ICC by Class I carriers for the year 1964.

The data on the cost of rails used in laying track include only the charges for buying the rail, inbound freight charges, and storage and handling, but exclude both delivery to the site where laid and also the costs of putting the rails in place. Nevertheless, just these costs total $5,986,652 for 852 miles of track, which averages $7,027 per mile, or $1.33 per foot.

The cost of rail vary according to the type of usage. For example, in usage for running and passing tracks and crossovers, the cost of rail was $7,838 per mile or $1.48 per foot. It would have been much higher but for the fact that 91 percent of the rail used in this way was second-hand rail, (at $55.30 per ton) versus only 9 percent of new rails (at $123.35 per ton). In contrast, for usage in way and yard switching tracks, the cost of rail was $6,840 per mile, or $1.30 per foot and 95 percent was second-hand merchandise (at $44.78 per ton).

The cost of ties used in laying track was even greater than the cost of the rail. As with rail, the tie costs reported represent essentially the purchasing cost and exclude the actual laying. The cost of ties was $8,119 per mile or $1.54 per foot.

There are, of course, several other elements of cost involved in laying track. These are land acquisition and right-of-way expenditures, engineering, grading of both terrain and bed, the laying of ballast, and the actual positioning and joining of ties and rail. The actual total costs will necessarily depend to at least some degree on the specific conditions in a given location. However, a "ballpark" estimate reported by railroad personnel is $75,000 to $100,000 per mile or $15.00 to $20.00 per foot, excluding land.

V. THE ORDER OF MAGNITUDE OF SOLID WASTE RAIL-HAUL COST

The problem of determining the cost of shipping solid wastes by rail is not essentially different from that of establishing the cost of providing any other service, except, it is much more complicated. There is, for example, a wide diversity of "common" costs that are not always applicable and even these costs may be subject to substantial variations depending upon local or regional transport developments.

1. General Conditions

Broadly speaking, rail-haul costing requires consideration of expenses for (a) the maintenance of way and structure and equipment, (b) the operations of yards, way and through trains, (c) general overhead and operating expenditures and (d) the investment. Each of these groups contains many items which might or might not apply to the costing out of a given rail transport service.

Exhibit X on the following page illustrates some of the cost items listed by the Interstate Commerce Commission for the operating expenses incurred by a railroad just in the maintenance of way and structures. It is obvious that some expenditures do not apply to the rail haul of solid wastes and that other expenditures, such as yard maintenance, will only apply if yards are needed for a given solid waste system. All the rail investment and operating cost elements will have to be analyzed, evaluated and packaged in order to focus on the rail haul of solid wastes in a proper way.

EXHIBIT X

APWA SOLID WASTE
RAIL-HAUL PROJECT

OPERATING EXPENSE CATEGORIES
FOR THE MAINTENANCE OF WAY AND STRUCTURES

Superintendence
Roadway maintenance - Yard switching tracks
Roadway maintenance - Way switching tracks
Roadway maintenance - Running tracks
Tunnels and subways - Yard switching tracks
Tunnels and subways - Way switching tracks
Tunnels and subways - Running tracks
Bridges, trestles, and culverts - Yard switching tracks
Bridges, trestles, and culverts - Way switching tracks
Bridges, trestles, and culverts - Running tracks
Elevated structures - Yard switching tracks
Elevated structures - Way switching tracks
Elevated structures - Running tracks
Ties - Yard switching tracks
Ties - Way switching tracks
Ties - Running tracks
Rails - Yard switching tracks
Rails - Way switching tracks
Rails - Running tracks
Other track material - Yard switching tracks
Other track material - Way switching tracks
Other track material - Running tracks
Ballast - Yard switching tracks
Ballast - Way switching tracks
Ballast - Running tracks
Track laying and surfacing - Yard switching tracks
Track laying and surfacing - Way switching tracks
Track laying and surfacing - Running tracks

EXHIBIT X

Fences, snowsheds and signs - Yard switching tracks
Fences, snowsheds and signs - Way switching tracks
Fences, snowsheds and signs - Running tracks
Station and office buildings
Roadways building
Water stations
Fuel stations
Shops and engine houses
Communication systems
Signals and interlockers
Power plants
Power transmission systems
Miscellaneous structures
Road property - Depreciation
Retirements - Road
Roadway machines
Dismantling retired road property
Small tools and supplies
Removing snow, ice and sand
Public improvements - Maintenance
Injuries to persons
Insurance
Stationery and printing
Employees' health and welfare benefits
Right-of-way expenses
Other expenses

Many ICC cost data differentiate between way-freight trains and through-freight trains. Way-freight train costs differ from through-freight train costs because way trains are operated primarily to do switching work. They distribute empty cars to the shipper and pick up the loaded ones. Only a small part of their cost are incurred in the line-haul movement of shipments.

In contrast, through-freight trains spend the greater part of their time in moving traffic over the line between crew-changing points. Very little of their cost is attributable to switching.

However, there are variations. Some way trains, for example, will cover a section of only 20 to 30 miles and do nothing but switching. Others will travel 100 miles or more in a day and haul some through cars in the direction of their movement. Furthermore, way trains may be virtually operated like through trains and occasionally do some local setting out or picking up of freight cars. In order to make their schedules, such trains may have less tonnage than that assigned to through trains which do no local work.

Thus, depending upon the local solid waste rail-haul situation, (e.g., the number of transfer stations or communities to be served enroute and the haul distance) the cost patterns of either way- or through-freight trains might apply. The through train cost might, as a rule, amount to only 70 to 80 percent of the way train cost per unit of movement. In almost all instances, the cost per carload or per ton-mile are higher for way-trains as compared to through-trains.

In conclusion, the cost differential between way-and through-trains suggests that the operations for the rail haul of solid wastes be developed to fit through-train conditions as much as possible. Local switching is expensive and should be minimized. In turn, the rail haul of solid wastes might evolve to utilize unit train or dedicated service train configurations rather than regular freight train operating patterns.

2. Benchmarks for Gauging the Economic Feasibility of Rail Transport of Solid Wastes from Potential Rail-Haul Anchor Communities

Solid wastes, in particular, steel and paper wastes, are currently shipped by rail. An analysis of data from the Interstate Commerce Commission suggests in a very broad average the following rail-haul cost profile:

CURRENT COST FOR RELATIVELY LOW VOLUME:
SHIPMENTS OF WASTES BY RAIL

Cost Item	Dollars per Ton	Percent of Total
Terminal	$1.82	52%
Line Haul	0.97	28
Loss and Damage	0.08	2
Total Out-of-Pocket	$2.87	82
Constant Cost	0.64	18
Grand Total	$3.51	100%

Average Number of Tons per Car: 49
Average Length of Haul: 125 miles

Source of Basic Data: Interstate Commerce Commission

The above cost data are strongly influenced by the underlying ICC cost sample. It includes a substantial number of paper waste shipments carried 214 miles on the average, with an average load of 28 tons per car at a cost of $6.36 per ton. The line haul cost for the waste paper shipments amount to

$2.30 and the constant cost to $0.88 per ton. Thus, it is conceivable that a higher compaction of the paper wastes might reduce the cost appreciably.

In evaluating the data, it should be highlighted that they reflect a relatively small volume--three to five car loads--of shipment as compared to unit train type operations. Also, the data do not reflect as high utilization of the equipment as is possible in daily solid waste rail-haul operations. Finally, the data include switching costs which may be quite substantial, e.g., in the order of $30 or more per car.

Nevertheless, the data may be used to indicate one order of magnitude for the economics of the rail haul of solid wastes. The line haul and the constant cost in the total sample add up to only $1.61 per ton even though they do not reflect the possibility of a reduced rate for a specially dedicated train service. Loss and damage expenditures do not apply to solid waste since waste, by definition, has no economic value.

The terminal cost, of course, requires further investigation and development work. In the rail haul of solid wastes the terminal costs appear to be strongly influenced by the overall configuration of the system as exemplified by the operation of transfer stations and their location in a given local rail network. There will, in most cases, be some terminal or terminal-type costs at both the origin and destination points.

Other economic parameters for the rail haul of solid waste can be derived from the cost of unit trains. Unit prices are frequently cited to range from four to seven mills per ton-mile. However, unit trains are employed to move rather large tonnages per train, for example 4000 to 8000 tons or more.

Thus, the cost of transporting solid wastes by rail, as a rule, may be found to lie between the unit train or rent-a-train cost and that quoted for the shipment of other commodities. Indications are given from various sources and are being further developed that for shipments of about 1000 tons a day and 100 tons per car, it may cost about $1.90 per ton to move the wastes about 50 miles. At 2500 tons per day and the same cars, this price may drop to about $1.30 per ton for about 50 miles and to about $1.70 per ton for about 100 miles. To move 2500 tons about 150 miles might increase the cost to about $2.05 per ton.

The above tonnage data suggest that a solid waste rail-haul system requires anchor communities to establish an economical operation. An anchor community thus may be defined as one having 1000 or more tons of solid waste to dispose of daily.

VI. RAIL NETWORK EFFECTS IN SOLID WASTE RAIL-HAUL SYSTEMS

There exists a great deal of freedom and flexibility in arranging rail networks and schedules. A schedule can be established so that a single train makes its rounds daily. However, it is important to notice that two (or more) individual trains can operate on a 48 hour round trip basis should circumstances warrant such a practice. This practice would enable a daily pick-up of all loaded railcars without limiting the time a train may need for either long distance transit or unloading at the disposal site.

The solid waste rail-haul network is, of course, basically defined by the available rail network. Solid waste rail haul might be confined to operations within a state or a region or require interstate transport. The system appears capable of functioning equally well in an intrastate as well as an interstate set-up. This flexibility is of great advantage since both the public and the officials concerned might prefer an intrastate system initially.

A rail network analysis represents a complex undertaking. Some tentative results of such analyses are shown in Exhibits XI, XII, XIII and XIV on the following pages for the States of Indiana, Michigan, Ohio and Pennsylvania.

The Exhibits present the available information in a highly simplified way to illustrate the basic approach and its effects. The following constraints should be kept in mind in viewing the maps:

1. not all communities are indicated which might benefit from the rail haul of solid wastes;

2. the network confines itself to the available tracks of the Penn Central Railroad to avoid inter-railroad switching charges;

3. the lines indicate how far solid wastes can be shipped at a cost of about $2.00 per ton or less at volume levels attainable from the communities indicated;

4. other routes based upon Penn Central tracks or trackage rights can be chosen; and

5. the potential for combining regional solid waste truck/trailer operations with a solid waste rail-haul system is not indicated.

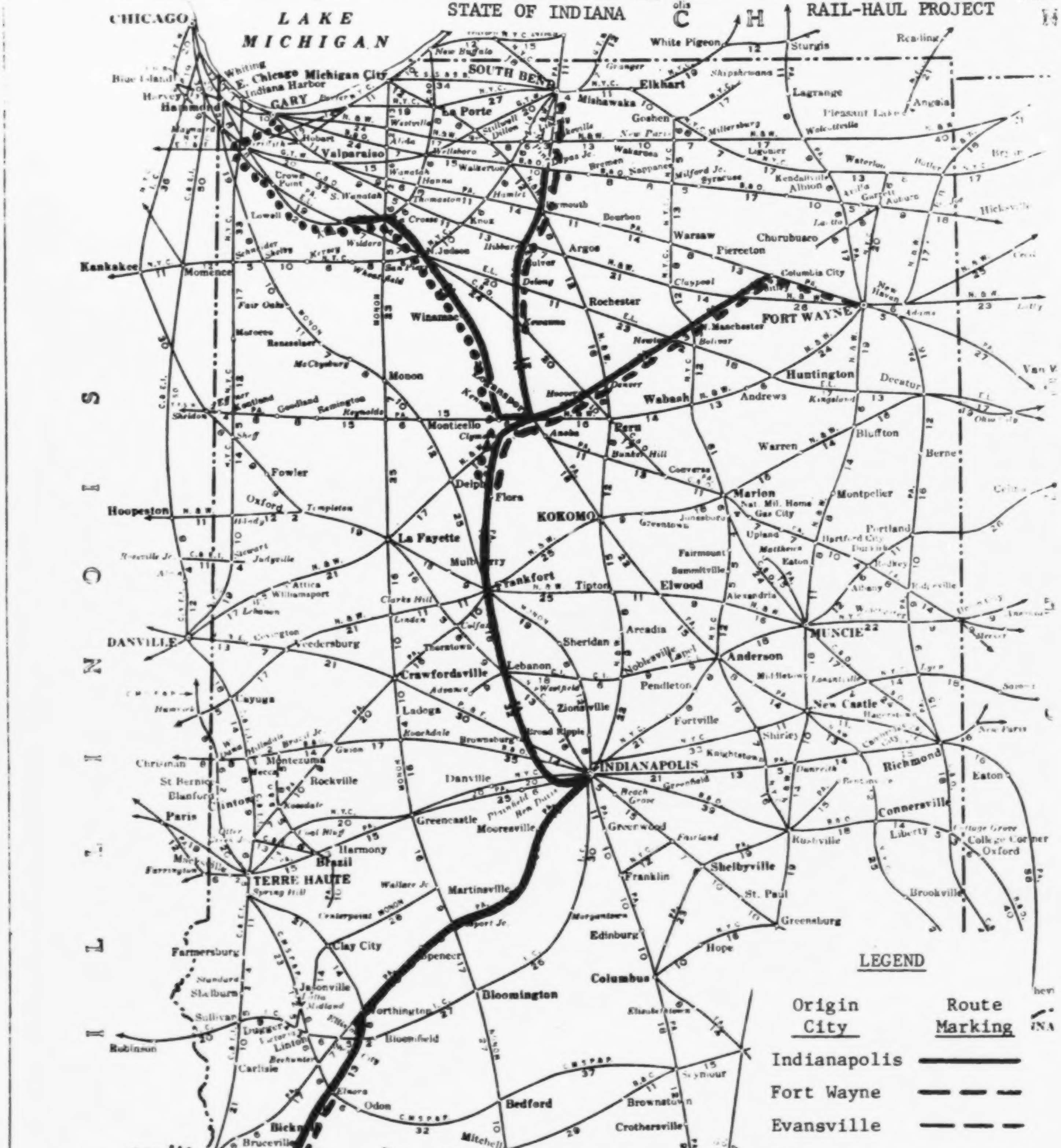
The effects of the solid waste rail-haul network are demonstrated by the line overlap. The areas of line overlap indicate where potential disposal sites may be located. Thus the network analysis shows that rail haul of solid wastes increases the flexibility for the location of disposal sites to a heretofore unachievable degree.

For example, the State of Ohio map suggests that the solid waste from the City of Columbus might be shipped for $2.00 per ton or less all the way to Toledo, Cincinnati, Middleport and almost up to Cleveland. Cincinnati's wastes might be shipped for the same cost half way between Columbus and Cleveland, almost half way between Columbus and Toledo and about three quarters of the way between Columbus and Middleport.

Disposal sites can be located all along the way where the lines overlap. As a result of this flexibility in the location of disposal sites it appears possible that many areas might compete for solid waste rail-haul disposal operations due to the economic benefits involved. To some degree, the disposal operations might produce benefits comparable to those derived from the location of a new industrial plant in a given community.

TENTATIVE SOLID WASTE
RAIL-HAUL NETWORK FOR THE
STATE OF INDIANA

EXHIBIT XI
APWA SOLID WASTE
RAIL-HAUL PROJECT


CHICAGO
LAKE MICHIGAN
GARY
Hammond
Michigan City
SOUTH BEND
Elkhart
Valparaiso
La Porte
Goshen
Warsaw
FORT WAYNE
Winamac
Logansport
Peru
Wabash
Huntington
Monticello
Delphi
Flora
KOKOMO
La Fayette
Frankfort
Marion
MUNCIE
Anderson
Elwood
Lebanon
Crawfordsville
INDIANAPOLIS
Richmond
Connersville
Shelbyville
TERRE HAUTE
Brazil
Martinsville
Bloomington
Columbus
Bedford
Vincennes
Washington
Princeton
EVANSVILLE
New Albany
LOUISVILLE
Jeffersonville
Kankakee
Hoopeston
DANVILLE
ILLINOIS
KENTUCKY
LEGEND
Origin City
Route Marking
Indianapolis
Fort Wayne
Evansville
Gary
South Bend
RAND McNALLY
HANDY RAILROAD MAP
Indiana
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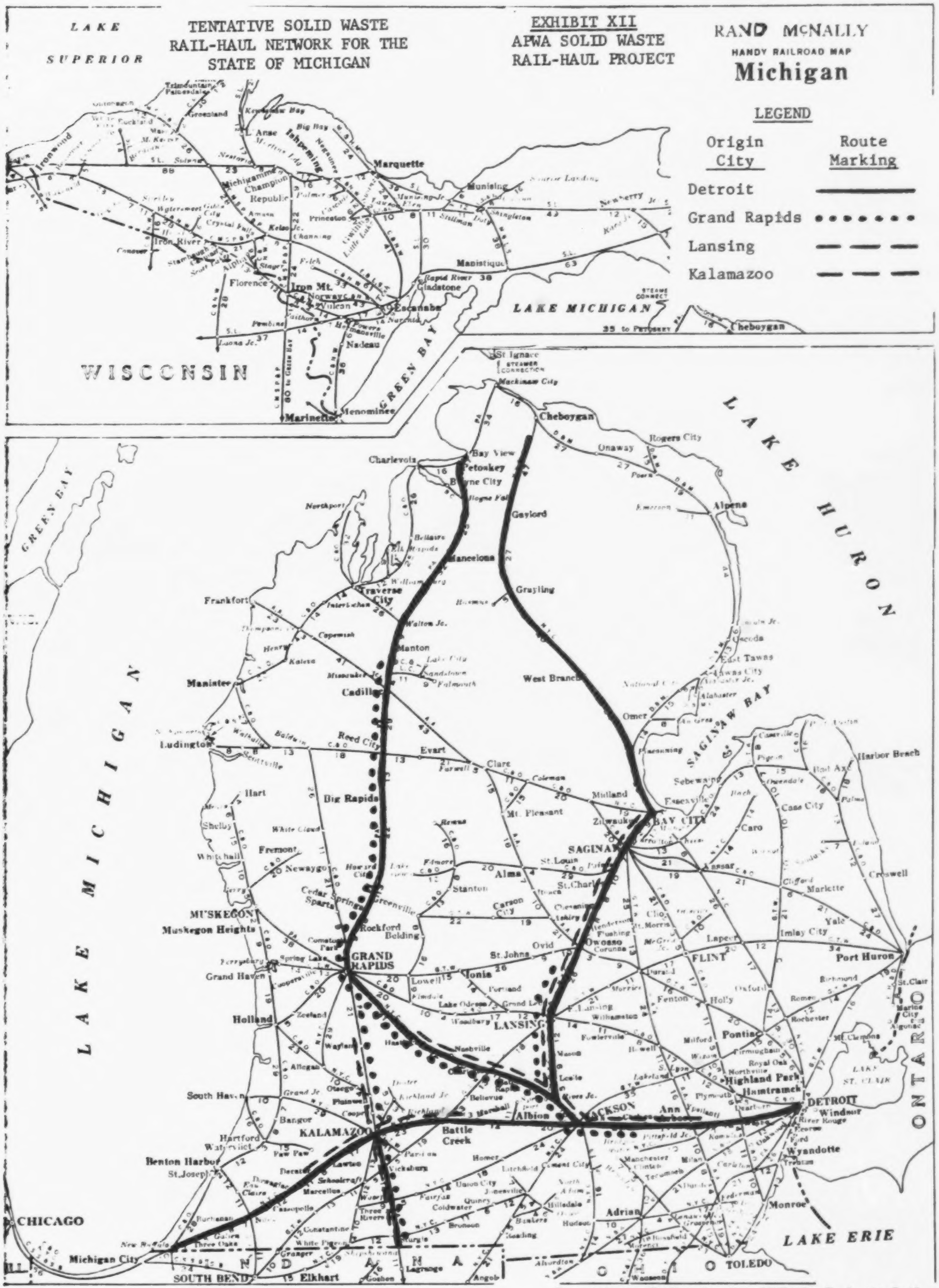

TENTATIVE SOLID WASTE RAIL-HAUL NETWORK FOR THE STATE OF MICHIGAN

EXHIBIT XII
APWA SOLID WASTE RAIL-HAUL PROJECT

RAND McNALLY
HANDY RAILROAD MAP
Michigan
LEGEND
Origin City
Route Marking
Detroit
Grand Rapids
Lansing
Kalamazoo
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
WISCONSIN
ONTARIO
GREEN BAY
SAGINAW BAY
INDIANA
OHIO
Marquette
Munising
Escanaba
Iron Mt.
Menominee
Marinette
St. Ignace
Mackinaw City
Cheboygan
Petoskey
Gaylord
Grayling
Traverse City
Cadillac
Manistee
Ludington
Big Rapids
Muskegon
Grand Rapids
Holland
Kalamazoo
Battle Creek
Jackson
Lansing
Saginaw
Bay City
Midland
Flint
Pontiac
Detroit
Port Huron
Ann Arbor
Monroe
Toledo
Benton Harbor
Michigan City
Chicago
South Bend
Elkhart
Alpena
Rogers City

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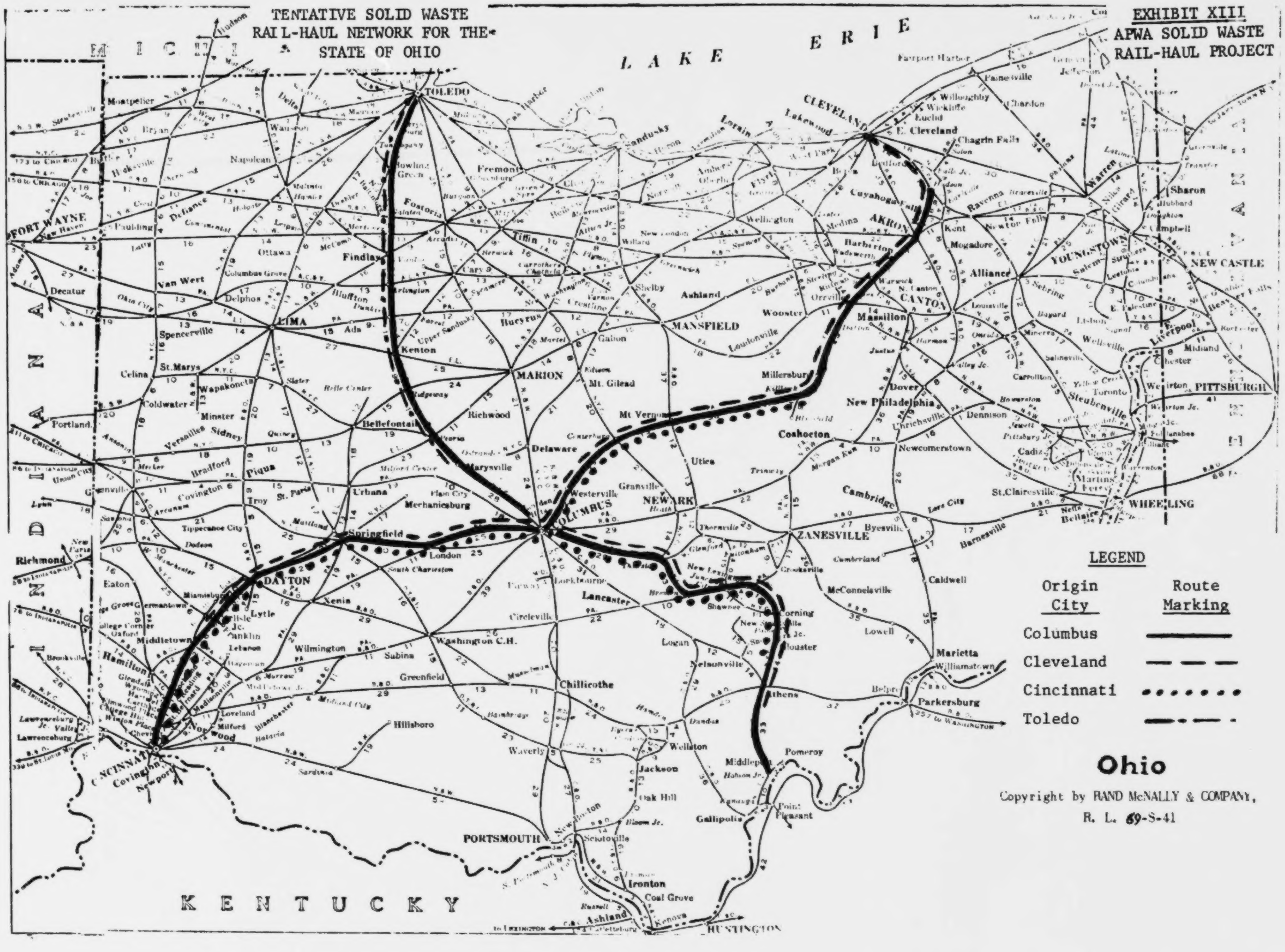
EXHIBIT XIII
APWA SOLID WASTE
RAIL-HAUL PROJECT

TENTATIVE SOLID WASTE RAIL-HAUL NETWORK FOR THE STATE OF OHIO


LAKE ERIE
MICHIGAN
INDIANA
KENTUCKY
TOLEDO
CLEVELAND
AKRON
CANTON
YOUNGSTOWN
MANSFIELD
MARION
LIMA
COLUMBUS
NEWARK
ZANESVILLE
SPRINGFIELD
DAYTON
CINCINNATI
PORTSMOUTH
PITTSBURGH
NEW CASTLE
WHEELING
HUNTINGTON
FORT WAYNE

LEGEND

Origin City	Route Marking
Columbus	———
Cleveland	— — —
Cincinnati	• • • • • •
Toledo	—·—·—

Ohio

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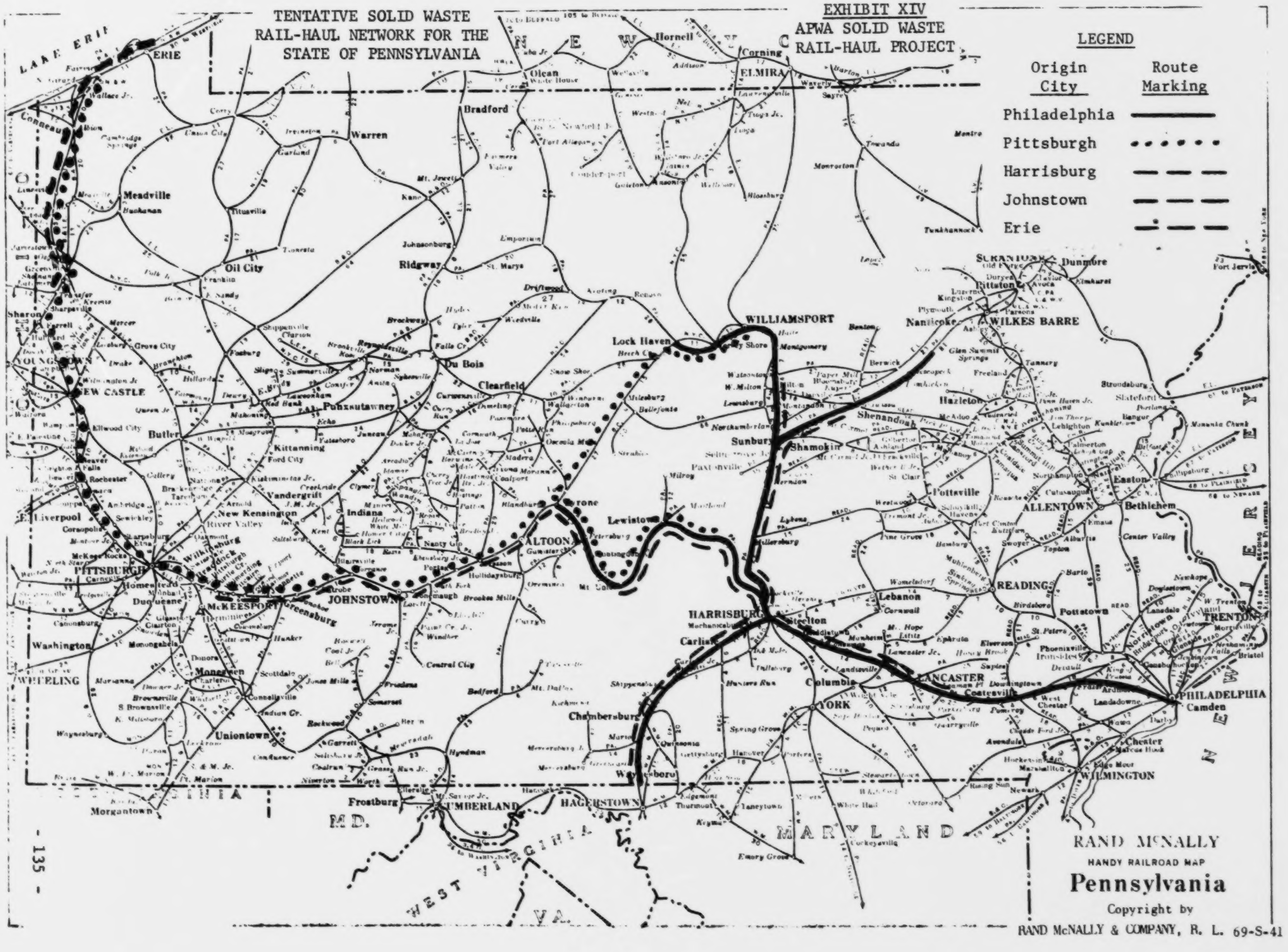
EXHIBIT XIV
APWA SOLID WASTE RAIL-HAUL PROJECT

TENTATIVE SOLID WASTE RAIL-HAUL NETWORK FOR THE STATE OF PENNSYLVANIA


LAKE ERIE
ERIE
Conneaut
Meadville
Warren
Bradford
Olean
Hornell
Corning
ELMIRA
Sayre
Oil City
Titusville
Sharon
YOUNGSTOWN
NEW CASTLE
Butler
Kittanning
Punxsutawney
Du Bois
Clearfield
Ridgway
Lock Haven
WILLIAMSPORT
Sunbury
Shamokin
Shenandoah
Hazleton
Nanticoke
WILKES BARRE
Pittston
SCRANTON
Dunmore
Stroudsburg
Bangor
Easton
Bethlehem
ALLENTOWN
Pottsville
READING
Pottstown
Lebanon
HARRISBURG
Steelton
Carlisle
LANCASTER
Coatesville
Columbia
YORK
Chambersburg
Waynesboro
HAGERSTOWN
CUMBERLAND
Frostburg
Bedford
Lewistown
Tyrone
ALTOONA
JOHNSTOWN
Indiana
Vandergrift
New Kensington
PITTSBURGH
McKEESPORT
Greensburg
Washington
WHEELING
Uniontown
Connellsville
Morgantown
Norristown
TRENTON
PHILADELPHIA
Camden
Chester
WILMINGTON
NEW YORK
NEW JERSEY
MARYLAND
MD.
WEST VIRGINIA
VA.
OHIO

LEGEND

Origin City	Route Marking
Philadelphia	———
Pittsburgh	• • • • • •
Harrisburg	— — —
Johnstown	— — —
Erie	—•— —

RAND McNALLY
HANDY RAILROAD MAP
Pennsylvania
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CHAPTER NINE - SANITARY LANDFILL OPERATIONS WITH RAIL HAUL OF SOLID WASTES

As noted in Chapter Three of this report, this study emphasizes the use of a sanitary landfill as the means of disposal. The sanitary landfill is already a proven process, can handle huge volumes of wastes, is relatively inexpensive, and can be rapidly implemented to alleviate a growing problem. This Chapter indicates some of the operational requirements encountered in rail-haul sanitary landfills, outlines the types of sites potentially available, and presents some results on the disposal of solid wastes in active strip mines.

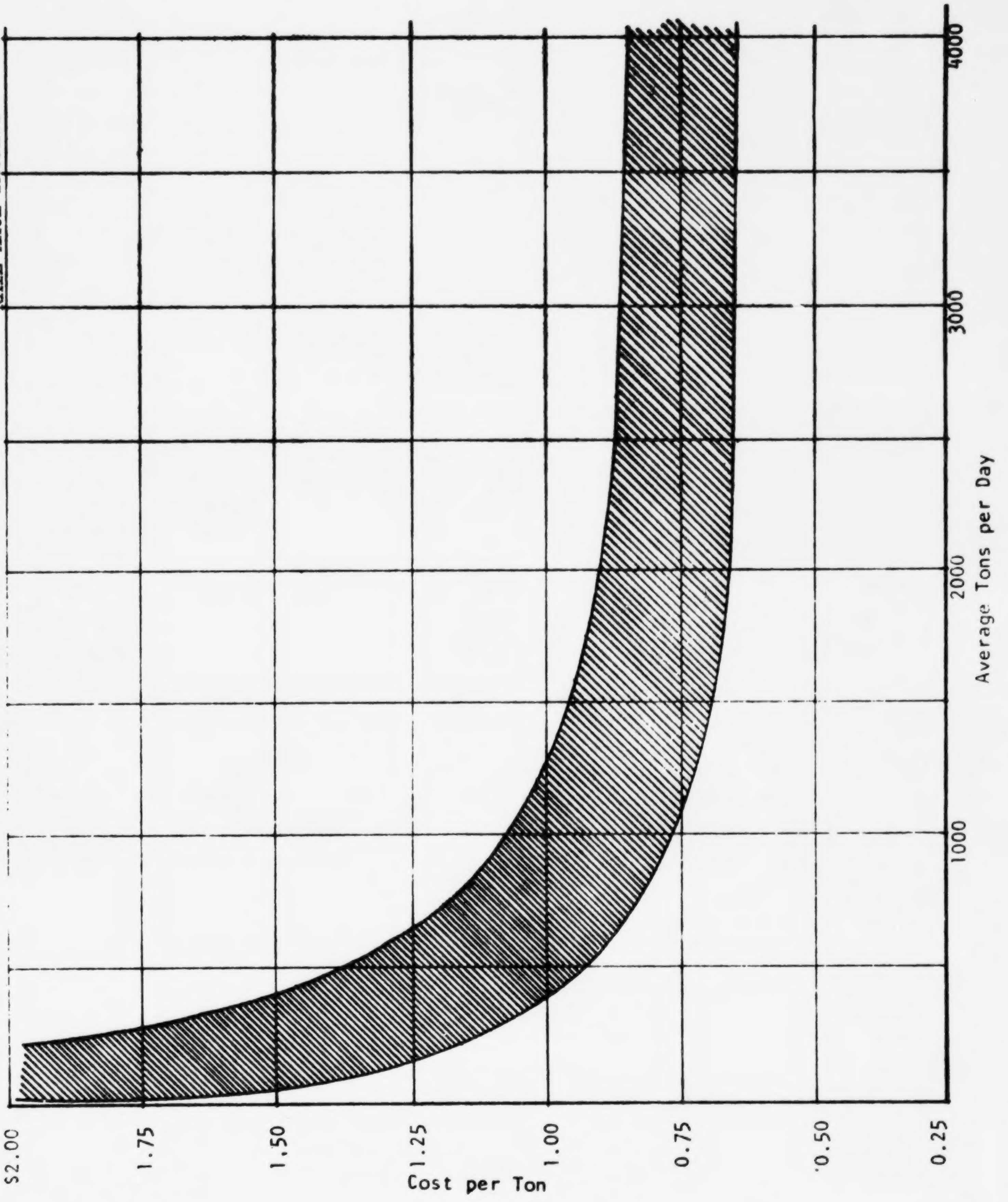
I. OPERATIONAL REQUIREMENTS AND IMPLICATIONS

No existing landfill is as large as the one which might become realistic in a solid waste rail-haul system. The largest system actually operated disposes of 8000 tons of refuse per day (Fresh Kills, Staten Island, NYC). In contrast, solid waste rail haul, as suggested by the network analysis, appears capable of delivering tonnages which require, at one site, a scale of disposal operations capable of handling 10,000 to 30,000 or even more tons of solid wastes per day.

As in many other fields, the cost patterns for sanitary landfills, too, appear to be susceptible to economics of scale. The larger the amount of wastes disposed of, the lower, tendentiously, the unit cost. As indicated in Exhibit XV on the following page, the cost curve drops sharply as the daily disposal volume increases. The costs shown exclude the cost of land and site development which, as a rule, amount to less than five cents per ton.

EXHIBIT XV
APWA SOLID WASTE
RAIL-HAUL PROJECT

RANGE OF SANITARY LANDFILL OPERATING COST



Source: American Public Works Association Research Foundation Project 67-1

In a very broad average, sanitary landfill costs are presently quoted to range from about 50 cents to about $2.50 per ton of refuse disposed of. In evaluating the cost data for the existing landfills it should be recognized that they refer to the disposal of unprocessed, and not to the disposal of processed, e.g., baled and/or highly compacted, solid wastes.

The increase in the scale of operations in solid waste rail-haul landfills suggest that perhaps a completely different type of equipment might have to be used to perform the on-site operations. At an average density of one ton per cubic yard for highly compressed solid waste, the disposal space volume requirements may amount to 10,000 to 30,000 cubic yards daily. At an average material density of 1000 pounds per cubic yard, as found with existing land-fill methods, the space requirements would increase to 20,000 to 60,000 cubic yards per day.

These data suggest that in a 250 working day/year, from 2.5 million to perhaps 15 million cubic yards of earth might have to be moved to provide the necessary space. The data also suggests that highly compacted refuse might produce considerable disposal cost advantages because of (a) less excavation, (b) less cover material per ton of waste, and (c) less hauling and perhaps put-in-place operations.

The type of equipment most likely needed for such large scale undertakings has already been developed for the mining industry in particular surface mining and for large scale civil engineering projects. For example, a bucket wheel excavator, capable of moving eight million cubic yards of earth per year, operates at about eight cents per cubic yard total cost. The cost of a tractor-scraper with a capacity of about 15 bank cubic yards per haul runs from about six to eight cents total cost per cubic yard. A high capacity shovel with a 100 cubic yard dipper and a three million cubic yard output per month costs about five to six cents per cubic yard in total cost.

The investment cost for the bucket wheel excavator is about $2.8 million, for the tractor-scraper about $46,000, and for the shovel about $8.4 million. Any specific equipment selection must, of course, be made within the framework of the total landfill operations and the individual cost/performance elements. It must be anticipated that, in this respect, numerous trade-off alternatives will need to be considered.

Finally, the rail-haul landfill operations differ from normal landfills in other respects, too. In most existing landfills the wastes are brought directly to the disposal point by the incoming collection trucks. In solid waste rail haul the landfill operations must include the additional hauling from a railhead to the actual disposal point and perhaps, in some instances, even all of the rail car unloading facilities. The type and scope of these unloading facilities depends, of course, upon the kind of rail car used, and on the nature of the transported work.

II. TYPE OF SITE CONSIDERATIONS

Potentially, solid waste rail haul might use a variety of landfill sites. By type, the following alternatives can be identified:

1. Sites Commonly used in Existing Landfills

Solid waste rail-haul landfilling differs from the existing methods primarily because of the scale of operations. It appears feasible to continue the use of the presently used methods of sanitary landfilling with some modifications. Due to the kind of equipment applied, a trench, for example, might be 100 to 200 feet wide and 50 to 100 feet deep.

2. Pits and Quarries

Pits and quarries exist almost universally but do not appear to lend themselves well to rail-haul solid wastes disposal. Primarily, they do not have, as a general rule, the needed capacity and lack, perhaps, a sufficient amount of inexpensive cover material.

However, the effective capacity of pits and quarries might be increased substantially by the use of highly compacted refuse. Also, the soil used for the intermediate cover may, perhaps, be substituted by man-made materials such as urethane foams or asphalt based substances. These materials can be formulated to be porous or non-porous, elastic or rigid, and fire resistant as well as insect and rodent repellant. Indications are given that some of these materials may be put in place at about a cost of from one to five cents per square foot.

3. Open Pit Mines

Open pit mines are very large but few in number. Examples include the iron ore mines in Minnesota and the copper mines in Utah or other states at the same longitude.

These mines would probably be adequate for the disposal of solid wastes in these areas, but are not ordinarily available. The current rate of technological advance tends to extend the life of a mine by making it economical to mine lower grades of ores. As a result mine owners are reluctant to forego this, often very profitable, opportunity, by having their pits filled with solid wastes.

4. Scrub Land

Scrub land exists to some extent in every state and province and appears to be a useful type of disposal site. However, scrub land is inoffensive and does not impel people to try to reclaim it. Consequently, it is not likely to be used except in states that have no better alternatives. Use of any given site would depend, of course, on accessibility, on remote location, and on the local soil and water conditions. Thus the case for solid waste disposal on scrub land might have to be made strictly on the basis of economics.

5. Marshes

A careful distinction must be made in the case of marshes. As a matter of conservation, one cannot arbitrarily seize on marshes for landfill sites. Some marshes are wildlife refuges or in tidal areas that have an important bearing on aquatic life and the fishing industries.

Yet, there are marshes which have no such value and might be suitable as landfill sites. As in all other cases, but specifically here, the site selection must take into account the potential for water pollution, flood damage and the like. A number of good examples do exist where marshes have been used for refuse landfills with highly beneficial results. Nevertheless, public relations appear to be the main problem in the disposing of solid wastes in useless marshes through sanitary landfilling.

6. Abandoned and Active Strip Mines

Mainly coal but also ore minerals are strip-mined. Substantial indications are given that coal strip mines might be prime locations for solid waste rail-haul landfills particularly in the states served by the Penn Central Railroad. They exist in many locales, are accessible by rail, have enormous capacities, and are generally regarded as eyesores which call for reclamation. Mine owners and operators tend to see a number of advantages in using strip mines for solid waste disposal.

Solid waste disposal in abandoned strip mines might be considered as a special type of ordinary sanitary landfilling. Abandoned strip mines appear to differ from other sites, primarily their topography. One disposal opportunity is provided by the abandoned last trench, another is found in the gaps between the spoil banks. This latter opportunity blends directly into the reclamation requirements of many states and would help the owners defray their reclamation costs. In a completely different approach, it also might be possible to work abandoned strip mines backwards in order to use the total area to better advantage.

Finally, it also appears advantageous to blend solid waste disposal operations into the normal activities of an operating strip mine. This procedure would add no or only little cost to the mine operation but would, on the other hand, eliminate all the costs of providing disposal space and of covering material for the wastes. Special attention has been given to this disposal possibility and some preliminary results are presented in a subsequent section of this Chapter.

7. Active Topography Developments

Due to the large amounts of material involved, solid waste rail haul offers ample opportunities for substantial topography engineering. The materials might be used to build hills in level areas, facilitate flood control, if proper sealing is guaranteed, and to develop recreation complexes for year-round leisure time activities.

8. Creation of Offshore Island and/or Land Reclamation in Lake and Coastal Areas

The large amounts of solid wastes that rail haul is capable of concentrating into one area offers a distinct possibility of creating offshore islands or developing land by filling in parts of large bodies of water. In this case, proper dyking and sealing are absolutely necessary to avoid any water pollution. Such "site preparation cost" might not be prohibitive, if the large disposal volumes are considered.

9. Ocean Disposal

Ocean disposal offers almost unlimited space for the disposal of solid wastes, if the wastes can be processed in a way to prevent harmful or undesirable effects on the environment. It would require that the rail-haul segment of the disposal system terminates at port cities or other suitable seaside locations.

The economics of ocean disposal appear to be rather attractive since no site preparation or on-site operations are required. For a haul distance of about 100 nautical miles offshore and a volume of about 20,000 tons per day, the necessary shipping costs have been estimated at 25 to 45 cents per ton. The shipping could be done in ocean-going, bottom-dump, barges or especially designed sea-going vessels.

It should be highlighted that ocean disposal requires definitely a suitable processing of the solid waste materials. The solid

> waste to be disposed of must be heavy enough to sink and must be put into a form stable enough to prevent floating of any components until they become waterlogged. The water pressure in the ocean at a depth of 1000 feet is about 450 to 500 psi.

One important aspect of the overall "type-of-site" considerations refers to the potential for land reclamation. Land reclamation might be accomplished by rail-haul solid waste disposal with no significant costs accruing to the reclamation effort. In addition, land reclamation could be accomplished within a very short period of time.

The project completion time is significant because of a natural reluctance on the part of elected officials to undertake certain long range projects in which the costs become visible from the start while results do not appear until years later. In these cases solid waste rail haul might provide a very desirable alternative. For example, by concentrating huge quantities of fill, the time needed for large reclamation projects might be cut down from, say, seven or eight years to one year or less.

This possibility has aroused considerable interest among practically all state officials with whom it has been discussed. Thus in connection with land reclamation, a demand for rail-haul solid waste disposal operations might actually arise in many places.

III. SOLID WASTE DISPOSAL IN ACTIVE COAL STRIP MINES

The possibility of disposing solid wastes through active strip mine operations has captured the attention of mine owners as well as officials from various levels of government.

1. The Relevance of Coal Strip Mines for Solid Waste Rail Haul

The U. S. Department of the Interior estimates that some 3.2 million acres, or 5000 square miles of land, have been disturbed by surface mining as of January 1, 1965. Only about one-third of this acreage is estimated to have been reclaimed, leaving two-thirds, or roughly 2 million acres, requiring reclamation. Although it is difficult to estimate the annual increase in the acreage disturbed by surface mining, the figure cited for 1964 is approximately 150,000 acres.

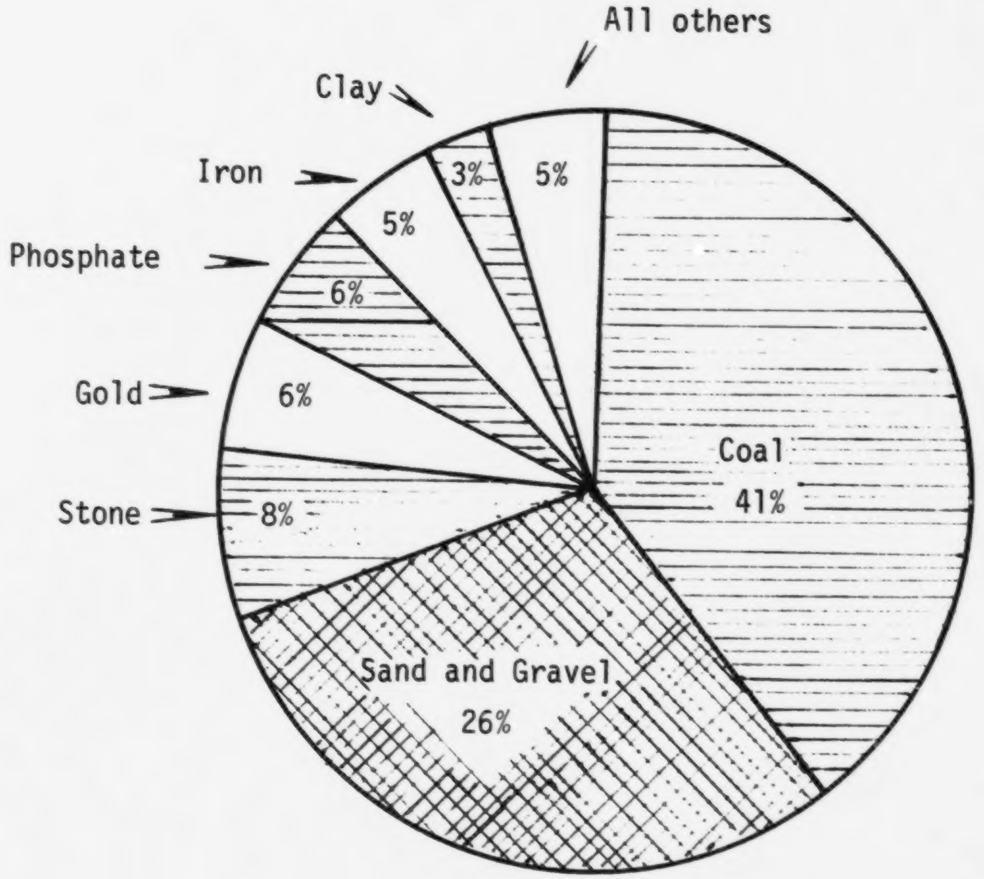
Exhibit XVI, on the following page, suggests that about 41 percent of the land disturbance is caused by the surface mining of coal. Sand and gravel with 26 percent of the total represent the second largest commodity. In the overall, the mining of seven commodities accounts for about 95 percent of the total land disturbed by surface mining.

The amount of coal mined by stripping increased by about 9 percent between 1965 and 1966, from approximately 165 million tons to approximately 180 million tons. Coal Age magazine forecasts that by 1985 the production of bituminous coal by stripping will increase to a minimum of 380 million tons or a maximum of 520 million tons. This is roughly two to three times the present level of production. Thus, active coal strip mines appear to offer amply potential sites for the disposal of solid wastes for many years into the foreseeable future.

EXHIBIT XVI

APWA SOLID WASTE RAIL-HAUL PROJECT

Percentage of Land Disturbed by Surface Mining of Various Commodities as of January 1, 1965



Total = 3.2 million acres

Source: U. S. Department of the Interior

Furthermore, the selection of coal strip mines for consideration within the context of solid waste rail haul appears to be supported by the geographical location of the mines. In terms of actual production, states east of the Mississippi accounted for 95 percent of the total coal produced in 1967, or some 549 million tons. States west of the Mississippi accounted for only five percent, or approximately 30 million tons. The States of Kentucky, West Virginia, Virginia and Pennsylvania rank highest in the total number of operative coal mines within their borders. Exhibit XVII on the following page indicates the total coal production as well as the number of mines by state.

Thus, the geographical distribution of the coal mines appears to be very favorable for solid waste rail haul since a significant share of the nation's highly urbanized areas is found east of the Mississippi. An analysis of the coal production activities, by states, indicates that mining operations are found either in or close to most industrial states.

EXHIBIT XVII
APWA SOLID WASTE
RAIL-HAUL PROJECT

MAJOR COAL PRODUCTION ACTIVITIES BY STATE

States East of Mississippi River	Total Coal Production (Deep, Auger & Strip) 1967 Tons (MM)	Number of Bituminous Coal and Liguite Mines, 1965	States West of Mississippi River	Total Coal Production (Deep, Auger & Strip) 1967 Tons (MM)	Number of Bituminous Coal and Liguite Mines, 1965
Alabama	15.2	206	Arkansas	0.3	8
Illinois	65.7	90	Colorado	5.4	79
Indiana	18.0	61	Iowa	1.0	28
Kentucky	96.3	1,827	Kansas	1.2	6
Maryland	1.4	69	Missouri	3.8	16
Ohio	45.7	417	Montana	0.4	13
Pennsylvania (Anthracite)	11.6	N.A.	New Mexico	3.6	8
Pennsylvania	79.0	1,140	North Dakota (Lignite)	4.0	29
Tennessee	7.3	230	Oklahoma	0.8	15
Virginia	37.9	1,271	Utah	4.5	31
West Virginia	152.2	1,660	Washington	0.06	5
			Wyoming	3.7	14
TOTAL:	519	6,971		30	252

Source: Keystone Coal Buyers Manual - 1968
Minerals Yearbook, 1966, U. S. Bureau of Mines

2. The Methods of Surface Coal Mining

There are, basically, three methods of surface mining utilized in obtaining coal. The first of these is area stripping, which refers to digging a series of parallel trenches in relatively flat or rolling terrain. The spoil material is placed in a previously made cut, and the mine then resembles the ridges of a washboard with an open trench where the last cut was made.

The second major method is contour stripping, which refers to digging around a hillside in steep or mountainous country. It creates a shelf bordered on the inside by an edge which forms a wall that may be as high as 100 feet and on the outside by an edge which forms a rim with a steep outslope covered by loose spoil material.

The third method is auger mining, which refers to boring horizontally into a seam to get more coal after the stripping is finished. A cutting head is drilled into the seam and coal is scraped out along the auger threads.

Although the total number of strip mines is less than that of underground mines, the productivity, in terms of average output per man per day, is twice as much. This fact is responsible, to a great degree, for the significant growth in coal mining by the strip method. Due to the rising costs of mining operations, it can be safely assumed that those methods which have high productivity will also have a continued growth.

In this respect, auger mining appears to have the highest productivity as compared to underground or strip mining. Compared in terms of averages for the total United States mines, underground mines have an average output per man per day of about 14 tons, strip mines about 32 tons and auger mines almost 46 tons. The auger method, however, is normally utilized only after it is no longer possible to strip due to an unfavorable overburden to coal ratio.

The investigation of the feasibility of solid waste disposal in active strip mines concentrates on area strip rather than contour mine operations, because of the multiple moving and handling costs involved in contour mining. It is also felt by mining companies that the relatively high operating costs of contour mines might make them unlikely sites for the disposal of solid wastes within the context of ongoing operations. An example of area strip mine operations is illustrated in Exhibit XVIII on the following page.

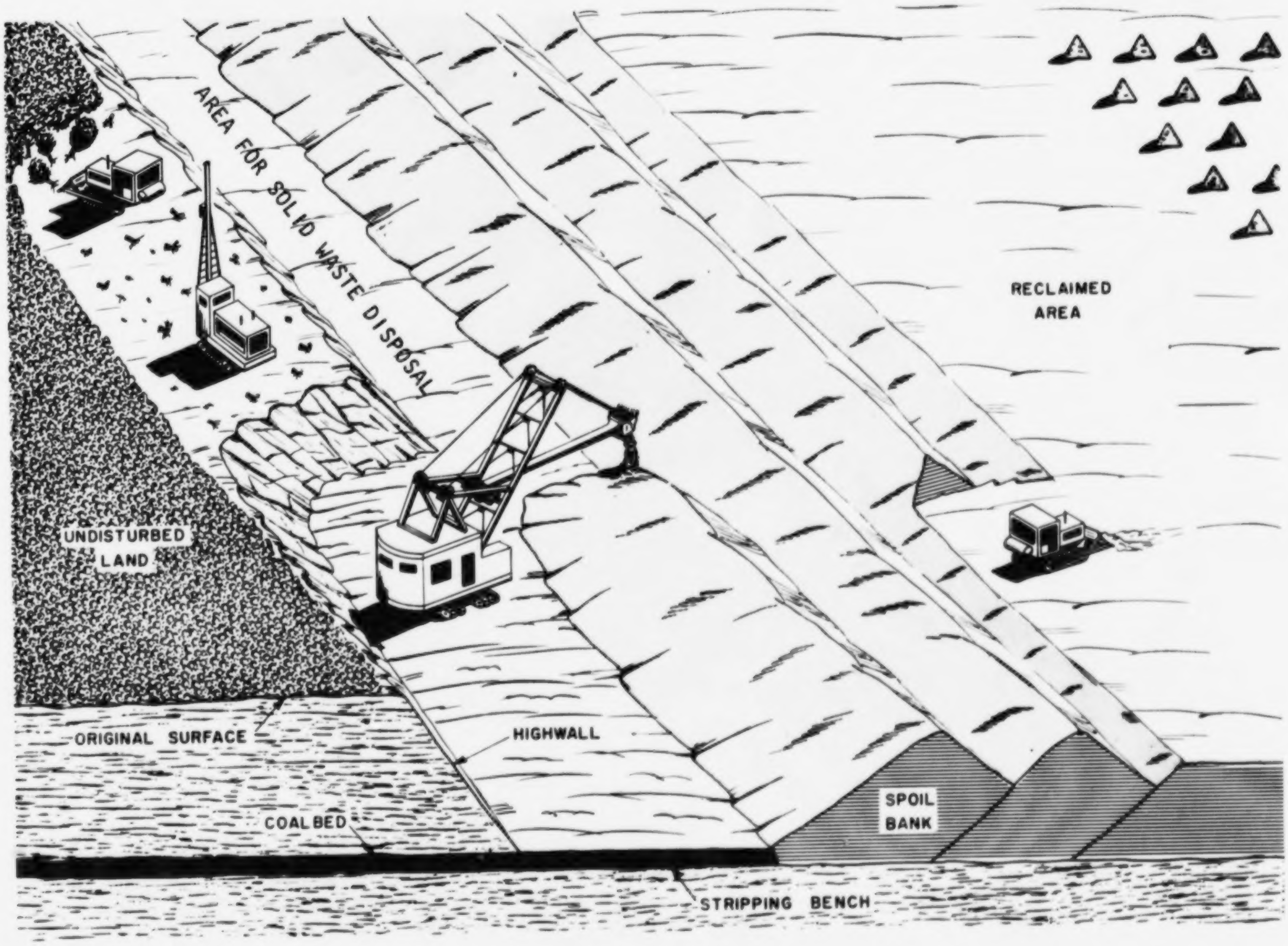
3. The Relevance of the Cost Structure of Area Coal Strip Mines for Solid Waste Disposal

In considering the cost structure of area strip mines it must be emphasized that each mine is operated somewhat on an *ad hoc* basis. There are many local variables which might affect cost data rather substantially. These variables include the amount of stripping that needs to be done, the overburden soil conditions, the length of haul, the demands on the roads that have to be built, coal yields and the number and types of trucks that can be used.

However, to identify and dimension the unit operations which might be affected by solid waste disposal, it is necessary to gauge the general cost structure of area coal strip mines. The cost range of ten major cost centers can be identified as follows:

EXHIBIT XVIII
APWA Solid Waste Rail-Haul
Project

Overview of active strip mine operations


AREA FOR SOLID WASTE DISPOSAL
RECLAIMED AREA
UNDISTURBED LAND
ORIGINAL SURFACE
HIGHWALL
COALBED
SPOIL BANK
STRIPPING BENCH

GENERAL DISTRIBUTION OF REVENUE IN AREA COAL STRIP MINES BY MAJOR COST CENTER

Major Cost Centers		Percent of Total Revenue*
1.	Stripping of the overburden	35-45%
2.	Coal loading, preparation, prospect drilling	5-10%
3.	Haulage by truck	3-10%
4.	Roads	0.5%
5.	Supervision on site	1-2%
6.	Land reclamation	0.5%
7.	Non-controllable expenses e.g., UMWA welfare, taxes, insurance	10-15%
8.	Depreciation	15-20%
9.	Royalties, general overhead	5-10%
10.	Profit before taxes	8-10%

---

*Total revenue, or mine realization, runs currently at about $4.50 per ton

A brief glance at this cost structure suggests that five to eight of the ten cost centers might be affected in varying degrees by solid waste disposal operations. Excluded are the stripping of the overburden and the operations dealing exclusively with the mining of coal. Based on a marginal cost analysis, the depreciation, the non-controllable expenses, and the royalty, sales and general overhead expenditures appear to be only slightly influenced by the solid waste disposal operations.

In drawing these conclusions, it must be recognized that profit, before income taxes, is most important in terms of a mining company's interest. This profit might be increased by (a) either direct royalty type payments or (b) a sharing in the cost anyhow incurred in the operations of a mine, or (c) a combination of both approaches. The opportunity for the disposal of solid wastes in active strip mines depends significantly upon the economic attractiveness of it to the mining companies although other considerations might perhaps gain substantial importance.

4. Analysis of Major Cost Elements for Solid Waste Disposal in Active Strip Mines

The process flow elements for solid waste disposal in active strip mines determine the cost of the operation. The major process flow elements can be grouped as follows:

a. transfer from the rail car
b. haulage to the pit, and
c. final deposition of the wastes

The implementation of the process flow elements depends, of course, upon the condition, specifically the density, in which the wastes will arrive. The operations for highly compacted and baled refuse will differ considerably from those needed for loose wastes.

Furthermore, the specific implementation of the process will depend upon the amounts of wastes handled per shift, the number of shifts per day, the trade-off implications with respect to the train waiting time, and the distance of haul on the site. A preliminary analysis suggests that on-site-haulage might constitute the major disposal cost element, as well as the primary variable, in the establishment of the total cost.

Following the on-site transportation practices in surface mines, the solid waste haulage might be performed by a mine railroad, mine trucks, conveyors and/or inclined skips.

Pneumatic or hydraulic pipelines are excluded from consideration because of the composition of the solid wastes or the form in which the materials might have to be handled.

The haulage of the wastes by truck appears to be universally applicable. However, investigations are under way to gauge the feasibility of using other modes of surface mine transportation in solid waste disposal operations.

In ascertaining trucking costs, it is necessary to determine the capacity, speed and length of haul. Statistics from the U. S. Bureau of Mines show that the average haul from the coal loader to the tipple is 4.6 miles. Conservative estimates by mine operators suggest that it is realistic to assume an overall on-site speed performance of 20 miles per hour. In this assumption the speed differentials between loaded and empty mine trucks are averaged out for most of the on-site conditions encountered.

The net load capacity of mine trucks varies widely. Most of the commonly used trucks are capable of carrying from 30 to 100 tons of pay load per trip. New equipment is coming on the market which by a tandem trailer combination is designed to carry from 150 to 250 tons of material. The utilization of the existing mine trucks requires, of course, that the solid wastes come definitely in a highly compacted form. To move unprocessed materials at an average density of 500 lbs/cu.yd.would, for example, require a 30 ton truck to provide space capable of containing at least 120 to 135 cubic yards.

The following mine haulage example is given to indicate the potential order of magnitude in the economics of on-site solid waste transport. The example is based on a 35 ton, 35 cubic yard truck, $75,000 purchase price, a five year depreciation period, 2500 working hours per year, a four mile one-way trip, 20 miles per hour speed, and a five minute loading and unloading time for each trip.

Within the framework of the above example, one truck is capable of moving seventy tons of baled solid wastes per hour. The corresponding hourly owning and operating cost, briefly, can be summarized as follows:

1. Fuel and lubrication	$ 1.90
2. Repair	3.10
3. Tires for off-highway duty	4.00
4. Depreciation	6.00
5. Operator	5.00
Total	$20.00/hour

Thus, based on these computations, it would cost about $0.285 to move one ton of solid wastes four miles or about $0.07 per ton/mile including the empty return trip.

It should be recognized, of course, that the waste haulage represents only one part of the total disposal cost. However, since the haulage appears to represent the largest cost element and since extra cover operations appear not to be required, it can tentatively be concluded that it is feasible to dispose of solid wastes in active coal mines at a cost of substantially less than one dollar per ton.

CHAPTER TEN - PUBLIC HEALTH AND ENVIRONMENTAL CONTROL IN WASTE RAIL HAUL

This Chapter is included in this interim report to indicate that public health and environmental control aspects are given the consideration necessary for determining the feasibility of solid waste disposal by the rail-haul method.

Occupational health, community sanitation and environmental pollution problems which could be encountered in a rail-haul disposal system are in principle of the same type as those found in other waste disposal systems. They arise from the presence of biological, chemical and physical agents contained in the wastes and also can be introduced by the application of different processing methods.

It is well known that different methods of disposal or solid waste processing may reduce or enhance some aspects of environmental pollution. Consequently, it is essential to evaluate the various aspects or elements of a given system to determine whether the system is, by itself, safe or whether specific public health and other environmental controls are needed additionally in order to eliminate unacceptable adverse effects.

In order to gain yardsticks and to deal with the specific aspects introduced by new system elements not present in currently used disposal methods, it was necessary to gather the information available in particular with respect to unprocessed solid wastes. Unfortunately, it must be emphasized that in many cases the relevant information is either fragmentary or inconclusive and often nonexistent.

Briefly the environmental factors considered in the present study and to be reported on at a later date include:

a) the identification of potential sources of pollution, occupational hazards, and nuisance factors;

b) their effect on different system elements;
c) the magnitude of the effects anticipated with respect to the high volumes to be handled by the rail-haul system;
d) the pollution related implications of processing; and
e) the development of suitable approaches as far as possible and/or feasible to eliminate pollution hazards.

A special effort is being made to determine whether and to what degree disease causing organisms are likely to be introduced into the system from different sources, their possible concentrations, and their likelihood of survival in the unprocessed and processed wastes. For this purpose, available epidemiological information has been gathered on diseases associated with municipal refuse, and on the environmental disease organism survival facts such as thermal death temperatures and time, which can cause the death of pathogens or foster their survival. The findings are being tabulated and will be presented in full, as emphasized above, at a later stage.

Furthermore, the effects of certain processing methods on pollution are also being investigated. A series of tests have been scheduled to determine the environmental properties of compacted wastes. These tests have been described briefly in the previous section dealing with the compaction test program. They include tests designed to determine the effects of compaction on pathogens and other microorganisms and to identify the chemical pollution potential of leachants released during the compaction process as well as those resulting from leachants from the compacted bales.

In this context some mention might also be made about the environmental considerations taken and their implications with respect to the development of a suitable compaction process. A high food and moisture content in the wastes provides an excellent environment for the majority of bacteria and fungi, including pathogens. The presence of these microorganisms can cause various adverse effects as, for example, the development of obnoxious odors in the transfer station or during compaction, and it could also introduce health hazards. It is therefore important to explore the possibilities inherent in the compaction and associated processing methods to utilize them as a means of destruction or impairment of microorganism activity. Compaction for example, might be used to release some of the moisture and organic matter found in the incoming wastes.

In addition, microorganisms not only require food and moisture for their survival, but also suitable conditions with respect to temperature, light and pH. For example, it has been established that many organisms cannot survive long at a temperature above 55° C. Similarly, many organisms cannot survive in a strongly acidic or alkaline medium. It has also been shown that airborne or surface bound bacteria, fungi and viruses can be destroyed effectively by UV radiation if the method is properly applied.

It is premature, of course, to indicate at this state the potential environmental effects of compaction processing on bacterial survival since relevant tests or data are not yet available. However, it might be speculated that since heat can be generated during compaction, it could provide a means of controlling or at least influencing bacterial life. The effectiveness will naturally depend on the temperature reached and also on the time requirements needed to cause the thermal death of the microorganisms. If compaction processing should require drying of the incoming refuse to achieve stability of the bales, it might provide simultaneously an opportunity for the impairment of bacterial growth and/or bacteria destruction.

It is not possible at this time to indicate the ultimate scope of the public health and environmental control work done with respect to the rail-haul of solid waste. Attempts, for example, are also being made to identify the sources of chemical pollutants and evaluate their implications by analyzing data such as presented previously in the tables on the composition of solid wastes.

All these data together with the respective environmental control implications will be presented in the final report. Specifically, questions such as the following need to be answered in order to dimension the proper operating patterns for solid waste rail haul:

1) How much liquid is released during compaction and needs to be disposed of in the transfer station and what is composition of such liquids?

2) How long can processed and unprocessed refuse be detained in a transfer station, and what are the most suitable conditions?

3) What noise and dust control methods have to be applied in order to protect the workers and to enhance good neighborhood relations?

4) What type of railroad car is needed considering various lengths of time the wastes would remain in the car?

5) Is it possible to identify railcar design specifications which would enhance the public health and environmental control performance of the system?

6) How long is it permissible for a loaded car to stay at the station or in a railroad switching yard?

7) What is to be done if a car loaded with refuse goes astray and ends up in varying regions or climates?

8) What are the implications of the high volume solid waste rail-haul landfills with respect to public health and environmental control?

The above questions are given to illustrate the type of work being done in order to determine the feasibility of a progressive solid waste rail-haul system. It is anticipated that the results to be presented in the final report will show that rail haul of solid wastes provides advantages over other disposal methods with respect to public health and environmental aspects.

CHAPTER ELEVEN - THE ORGANIZATIONAL, FINANCIAL AND LEGAL IMPLEMENTATION OF TRANSPORTING SOLID WASTES BY RAIL

This Chapter deals with the management aspects involved in the implementation and execution of solid waste rail haul. Many factors and considerations are, of course, involved. This Chapter presents briefly some indications of the work being done and/or considered with respect to the solid waste rail-haul communities and the states in which solid waste rail haul may take place. In addition, some organizational alternatives for the execution of a solid waste rail-haul system are outlined to conclude this interim report.

I. SOLID WASTE RAIL-HAUL COMMUNITIES (COMMUNITY WORKSHOP)

The rail haul of solid wastes starts, of course, on the local level of government, i.e., in the communities where the wastes are generated. The final decision on the application of waste rail haul will have to be made, in most cases, by local community leaders. Also the merits of waste rail haul must ultimately be proven on the community level.

The community related work is done, to a large extent, with the help of a community workshop which is conducted with the public agencies participating in this project. It is obvious, that in terms of rail-haul feasibility, the importance of the community workshop can hardly be overestimated.

The objective of the community related efforts is to determine in close cooperation with the respective officials

a) whether or not rail haul is feasible and/or adaptable for the waste disposal in the given community;

b) how the waste rail haul should be executed in terms of all the local conditions to be considered; and

c) what specific benefits can be identified and dimensioned in terms of both performance and cost.

The community workshop efforts appear to be necessary in a twofold way with respect to solid waste rail-haul feasibility. In addition to developing the information needed by community leaders for deciding on the local applicability of solid waste rail haul, they are to establish simultaneously the parameters needed to tailor rail-haul developments to specific local requirements advantageously. For example, it is important to ascertain which types of solid waste are desired to be handled by a given rail-haul system and whether and how private waste disposal organizations may participate in a system established by a local government.

Among other factors, the logistics of solid waste transport appear to be of great significance for the local solid waste disposal operations. Involved are the ways and means of handling and moving the wastes from the location where they are generated to the point or points of disposal.

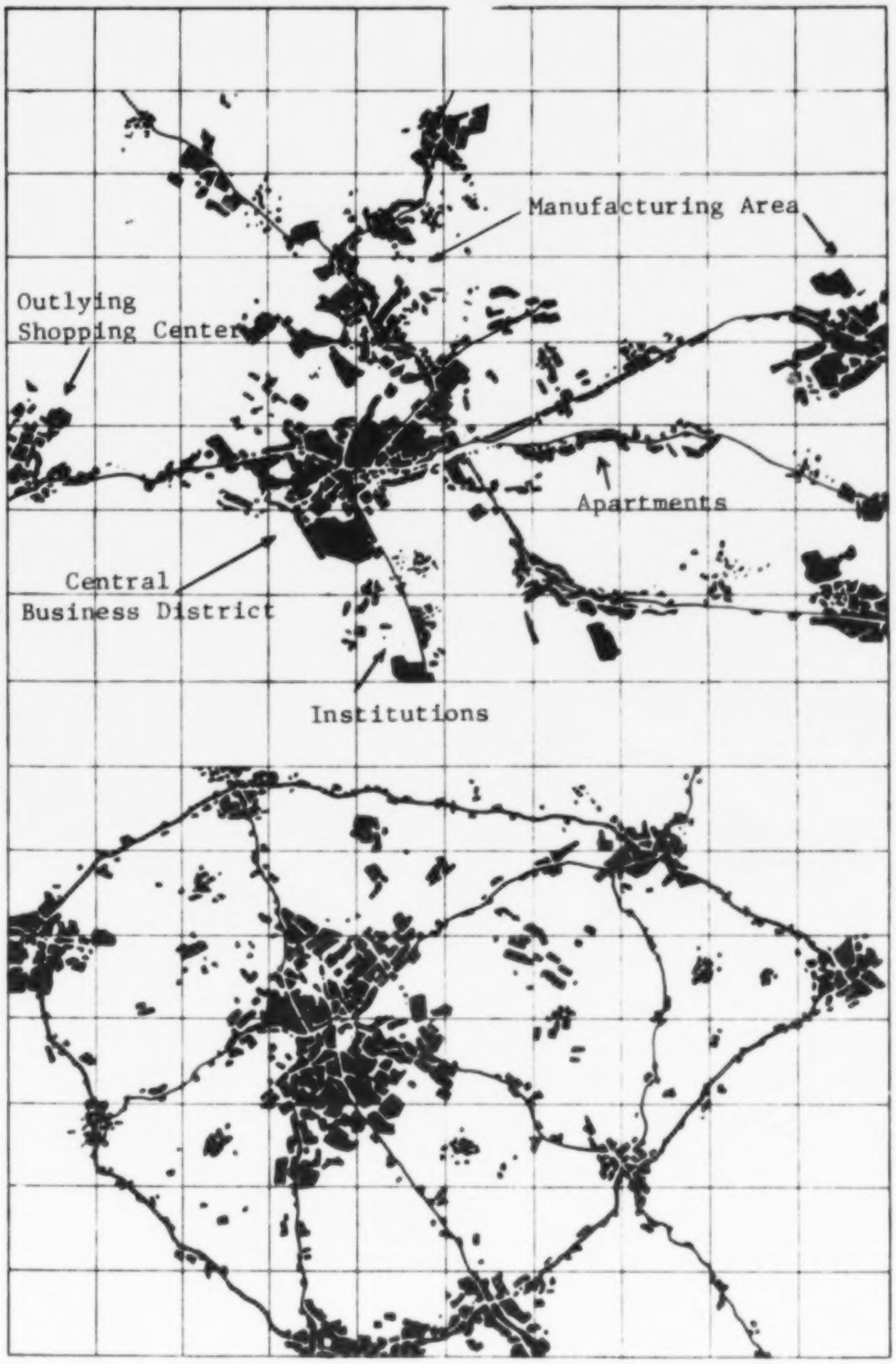
Exhibit XIX on the following page shows two basic types of community layout with respect to the generation of solid wastes. The difference in the layouts reflects the spatial structure of the major rail or highway transportation arteries.

The black areas in the exhibit denote the locations where the generation of solid wastes is rather intensive. These areas include the downtown business and office complex, shopping centers, industrial parks and high rise apartment buildings. The white areas represent the normal residential settlements where the generation of solid wastes is not as concentrated but diffused over a wide area.

EXHIBIT XIX

APWA SOLID WASTE RAIL-HAUL PROJECT

X-Ray Type Patterns Reflecting the Spatial Distribution of the Solid Waste Generation with Respect to Volume Concentration


Manufacturing Area
Outlying Shopping Center
Apartments
Central Business District
Institutions

Source of basic map: Public Administration Service

It is obvious that significant indications for the location of transfer stations and for the type of transfer station needed in a given location become apparent through an inspection of Exhibit XIX. In downtown areas, for example, transfer stations might be located underground. The wastes could be transported to the station by a vacuum system as it has been developed in Sweden. In most American cities the distance from the center to the edge of the downtown area is approximately one to two miles or less and the vacuum systems are already used for such distances.

It should be highlighted, of course, that all transfer stations need not be located on rail sites necessarily. It is entirely conceivable that an intermediate truck or trailer transfer be incorporated into the local part of a rail-haul system if savings in the collection cost should warrant such a system configuration.

In the overall, solid waste rail haul appears to provide the potential for becoming a powerful tool to enhance local efforts aiming at total environmental control. By its mere existence rail haul will affect more or less all solid waste management efforts on the community level in a more or less comprehensive way.

Solid waste rail haul, for example, might restructure the financial aspects of the total local solid waste disposal system, it might lead to new laws and/or ordinances regulating solid waste disposal on a broad front, and it might introduce long term performance guarantees to become the rule in municipal purchasing.

Due to the long service life of certain types of equipment it appears necessary to view rail haul as well as competitive modes of disposal within the framework of a 15 to 20 year operating period. This, in turn, requires that the information on the generation of solid wastes, collection trends, and local disposal alternatives be scaled accordingly.

II. STATES AND SOLID WASTE RAIL HAUL

Solid waste rail haul will operate by its very nature on a regional, superregional, intrastate or even interstate basis. Thus it might be advisable or necessary for states or state agencies to become involved.

Similar to the community related efforts the state related activities of the project are scheduled to include a workshop for state officials. Tentatively the state workshop is to pursue three basic objectives:

a) to discuss the functions states might execute for the setting up and operations of a rail-haul system,

b) to identify areas where existing state laws and regulations might impede an optimum waste rail-haul performance, and

c) to enlist the cooperation of appropriate state agencies so that waste rail haul might be executed in the public interest all the way.

Since waste rail-haul operations might concern the jurisdictions of many state agencies, it appears necessary to confine the workshop, at least initially, to the departments mainly involved. Tentatively, this might require a participation of the following agencies or their equivalents:

1. Sanitation,
2. Public Utilities--if they deal with the regulation of interstate rail transport,
3. Conservation--resource development,

4. State planning and industrial development, and
5. The Governor's office--because of the political implications of solving the problems of many communities on a statewide basis.

Specifically, inputs to the project from the state workshop might deal with subjects such as:

... the identification of state and federally owned land,
... the location of disposal sites considering both rail transport logistics and state resource development plans,
... the operation of a statewide sanitary landfill network,
... the public relations necessary to allow rail haul to function effectively, and perhaps
... the development and execution of a rail-haul demonstration project on a statewide basis.

It is anticipated that the state workshop will provide benefits of material assistance for the implementation of solid waste rail haul.

III. ALTERNATIVES FOR THE EXECUTION OF SOLID WASTE RAIL HAUL

The responsibility for the ownership and operations of a solid waste rail-haul system may be executed in various ways and many alternatives are given. Basically, a solid waste rail-haul system consists of three major system elements and each one of these three elements may be operated by a different organization.

The structure of a given solid waste rail-haul organization may reflect various degrees of public and/or private involvement. For example, an organization responsible for one or all of the solid waste rail-haul system elements may involve exclusively or in various combinations one or more than one of the following legal entities:

a) a single municipal government,
b) more than one municipal government,
c) one or more than one agency of a single state,
d) one or more than one agency from several states, and
e) one or more than one private firm or organization including railroads and/or their subsidiaries.

Exhibit XX on the following page gives some examples of alternatives for the execution of a solid waste rail-haul system. The exhibit illustrates the great flexibility solid waste rail haul provides potentially for tailoring the system to the existing needs and capabilities. It is judged at the present time, that this flexibility in the execution of the effort will become a major factor for a speedy as well as responsible implementation of solid waste rail haul.

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This concludes the interim report on the APWA solid waste rail-haul study. Being an interim report this presentation by necessity had to be limited and in certain respects inconclusive. Any comments or suggestions that might be made are invited most cordially.

EXHIBIT XX

APWA SOLID WASTE RAIL-HAUL PROJECT

ILLUSTRATION OF ALTERNATIVES FOR THE ORGANIZATIONAL IMPLEMENTATION OF SOLID WASTE RAIL HAUL

System Alternative	Transfer Station(s)	Rail-Haul Link	Ultimate Disposal
I	One municipal government	The same municipal government*	The same municipal government
II	Private organization	The same private organization*	The same private organization
III	State organization	The same state organization*	The same state organization
IV	One or more than one municipal government at the system's orginating point	Railroad Company	One or more than one local government agency with jurisdiction at the disposal point
V	Public/private cooperative organization **	Public/private cooperative organization	Public/private cooperative organization
VI	Railroad company	Railroad company	Railroad company
VII	Municipal government	Railroad company	State agency
VIII	Private organization	Railroad company	Local government and/or state agency

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* The organization may own the railroad cars and engines needed and just lease or purchase trackage rights.

** This could include one or more public agencies and one or more private firms such as the tenants of an industrial park.

OTHER SOLID WASTE DEMONSTRATION PROJECT REPORTS:

Project No.	Grantee	Report
D01-UI-00004	City of Madison, Wisconsin	Solid waste reduction/salvage plant; an interim report, City of Madison pilot plant demonstration project. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 25 p.
D01-UI-00018	City of Santa Clara, California	Solid wastes landfill stabilization; an interim report. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 146 p.
D01-UI-00026	Quad-City Solid Wastes Committee Paterson, New Jersey	Quad-City solid wastes project; an interim report, June 1, 1966 to May 31, 1967. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 192 p.
D01-UI-00038	District of Columbia *Final Report: Phase 1*	Special studies for incinerators; for the Government of the District of Columbia, Department of Sanitary Engineering. Public Health Service Publication No. 1748. Washington, U.S. Government Printing Office, 1968. 80 p.
D01-UI-00046	County of Los Angeles, California	Development of construction and use criteria for sanitary landfills; an interim report. Cincinnati, U.S. Department of Health, Education, and Welfare, 1969. 267 p.
D01-UI-00060	City of Des Moines, Iowa	Collection and disposal of solid waste for the Des Moines metropolitan area; a systems approach to the overall problem of solid waste management; an interim report. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 326 p.
D01-UI-00070	Genesee County, Michigan	Solid waste disposal study; technical report; Genesee County, Michigan, June 1968. Cincinnati, U.S. Department of Health, Education, and Welfare, 1969. 252 p.

Project No.	Grantee	Report
D01-UI-00073	American Public Works Association Research Foundation, Chicago, Illinois	The Tezuka refuse compression system; a preliminary report. Cincinnati, U.S. Department of Health, Education and Welfare, 1969. 47 p.
D01-UI-00080	Metropolitan Sanitary District of Chicago	Land reclamation project; an interim report. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 338 p.

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